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Final Report

The Fishes of Champaign County

F-76-R

L. Osborne, P. Bayley, D. Dowling, R. Larimore,

C. Nixon, J. Peterson, D. Szafoni and D. Wood

Center for Aquatic Ecology
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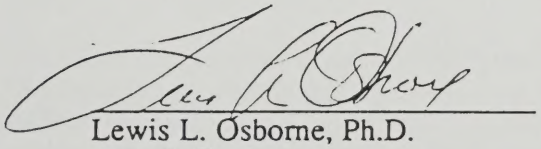

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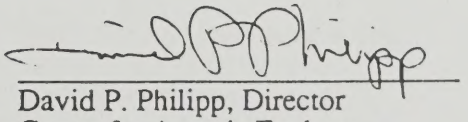

David P. Philipp, Director
Center for Aquatic Ecology

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Research project F-76-R, The Fishes of Champaign County, was conducted with funding from the Federal Aid in Sport Fish Restoration Act (Dingell-Johnson Program) - a cooperative program between the states and the U.S. Fish and Wildlife Service. The project is sponsored by the Illinois Department of Conservation. The form, content, and interpretations of data are the responsibility of the Illinois Natural History Survey and the University of Illinois, and not of the Illinois Department of Conservation or other cooperating agencies/organizations.

EXECUTIVE SUMMARY

Stream fishes in the six drainage basins of Champaign County, Illinois were quantitatively sampled from June 1987 through October, 1988. Species richness and composition were compared to three historical fish surveys that also sampled the same locations between the late 1890's through 1960 at approximately a thirty year interval. Data on land use, water quality, physical habitat, benthic macroinvertebrate abundance, crayfish distribution and abundance and prey utilization of several sportfish were also assessed and related to the abundance and distribution of sport fish populations in an attempt to identify limiting factors. The land use/cover conditions in Champaign County during the 1950's were quantified and compared to those that existed during the present survey in an attempt to identify potential land use changes that may be associated with the distribution and abundance of sportfish populations.

A total of 81 independent fish taxa from unrepeated samples were used for comparison among all four surveys (three historical surveys and present survey). We found that species richness of the fish communities was remarkably consistent among surveys. Despite this consistency, substantial variation occurred in the composition of fishes among surveys. General increases in percentage occurrence through time were noted for blackstripe topminnow, bluegill, common carp, grass pickerel, green sunfish, largemouth/spotted bass, longear sunfish, striped shiner, johnny darter, and silverjaw minnow. Biomass of sportfish, including largemouth bass, spotted bass, smallmouth bass, rock bass, channel catfish, and grass pickerel, increased during the last 30 years in Champaign County streams, but were still low compared to other streams in Illinois. Historical evidence indicates that poor water quality may have been a major limiting factor to sportfish in the 1950's. Results from the present survey indicate that water quality has probably improved to some extent during the past 30 years, and that physical habitat currently limits the distribution and abundance of most sportfish in Champaign County. The limiting physical habitat is a function of land use practices associated with agriculture, particularly channelization and channel maintenance for drainage. Reaches where water quality remains limiting also appear to be associated with non point source contamination associated with agricultural practices, particularly fertilizer application. The negative association between the density and biomass of sportfish and important prey items such as crayfish further suggested that food may be limiting the abundance of sportfish in some areas.

We also examined the impacts of the 1988 drought on fish, their prey, and their habitat and the recovery process at three previously desiccated stream reaches through 1990. No differences were found in the total densities and biomass of macroinvertebrates at non-desiccated stations attributable to the drought. Total losses were observed in desiccated reaches. Significant reductions in the densities of crayfish in both desiccated and undesiccated reaches were observed. Analyses suggest that macroinvertebrate community structure did not recover by the end of 1989 to pre-drought conditions at two of three study sites that were desiccated during the drought. Preliminary analyses of samples collected in 1989 and 1990 also indicated that fish recovered rapidly from this single 'pulse' disturbance when more typical conditions returned and displayed a colonization process similar to that which normally occurs as fish move upstream to spawn or disperse from winter habitats. A model was developed to estimate the loss of fish due to the drought in the Salt Fork basin. We estimated that 17% of the normal summer fish biomass (90 tons) was lost in this basin during the drought of 1988. This provides a conservative estimate of the loss that would be expected if continuous water extraction were permitted and were to become widespread during the summer months.

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STUDY 101. FISHES OF CHAMPAIGN COUNTY

INTRODUCTION

Streams and their aquatic communities are directly influenced by the past and present activities of man. In Champaign County, marshes and tall grass prairie have been converted to farm lands that have been subjected to intense fertilizer and pesticide applications, converted to cities, and have been the dumping ground of domestic and agricultural wastes. Such practices can be expected to have significant influences on aquatic communities. An understanding of man's influences on aquatic systems is therefore essential for the management and preservation of the associated streams. The availability of historical information on the fish communities inhabiting the streams of Champaign County (Forbes and Richardson 1908, Thompson and Hunt 1930, and Larimore and Smith 1963) in conjunction with data collected in this study provided a unique opportunity to relate nearly a century of biological observations with dramatic changes in land drainage, agriculture, and urbanization. Thus, the importance of this study is not restricted to its geographic location, or to a unique assemblage of fish, but rather, to long-term patterns in fish community composition and structure in a midwest, agricultural setting. The concomitant changes that have occurred in a highly developed agricultural and urban region likely influence the distribution and abundance of stream fishes, their food supply, and the quality of their habitat. Understanding the long-term implications of such changing land use practices on stream fish assemblages and on sport fish populations is critical to sound environmental management and planning.

STUDY 101. OBJECTIVES

The objectives of this study were to:

1) evaluate the qualitative changes in fish species during the past 90 years in Champaign County streams and to identify components of the assemblages that have changed significantly;

2) quantify changes in urbanization, forestation, and farming practices within the watershed of fish sampling stations during the past 30 years;

3) assess the relationship between various instream and riparian habitat parameters and fish community structure in the streams of Champaign County;

4) assess the relationship between stream water chemistry, food supply, physical habitat, and sport fish populations (particularly smallmouth bass) in a main watershed draining Champaign County and attempt to identify factors limiting the distribution of smallmouth bass.

The following three sections of this report, Jobs 101.1, 101.2, and 101.3, address each of these objectives and provide detailed methodologies to permit future replication of the study.

JOB 101.1 FISH COMMUNITIES

INTRODUCTION

The objectives of this job are to analyze changes in the fish species of Champaign County during the past 90 years and to identify components of the fish assemblages that have changed significantly. This project builds on previous surveys conducted at close to 30-year intervals by Forbes and Richardson (1908), Thompson and Hunt (1930), and Larimore and Smith (1963).

METHODS

The aim was to replicate as many of the previous sites as possible, and to use the same sampling methods used by Larimore and Smith (1963). Sampling of fish is a major consideration when comparing fish populations, communities, and even their presence or absence. The first two surveys used the minnow seine. Details of Forbes and Richardson's (1908) survey, which was part of a larger statewide survey conducted mostly in 1899, are understandably lacking because of the predominantly taxonomic nature of that study. We found clear species and location information for 46 samples from the original data cards of Forbes and Richardson. However, their data cards did not always show clearly the quantities of fish caught for every species noted. Therefore, we only used their data for presence/absence analysis.

Thompson and Hunt (1930) completed a more comprehensive survey during 1928-29. All but one of their 125 stations were replicated by the next two surveys. They collected most of their samples using a seine net 10 feet by 4 feet deep with a one-sixth-inch square mesh. Five additional samples were taken with a 75 feet by 6 feet deep seine with a one-inch square mesh. Larimore and Smith's (1963) survey in 1959 used the more efficient 30-foot electric seine between block nets (Larimore 1961; Bayley et al. 1989) and the net seine for qualitative samples. They took a total of 198 samples, of which 48 were repeated samples (mostly in 1960) at stations where qualitative net seine samples were taken, 82 were quantitative samples using the electric seine between block nets, and the remainder were qualitative net seine samples. Larimore and Smith's 'cruising' samples, which were seine net hauls taken outside the block nets, were not included in this analysis.

The present study replicated the sampling methods of Larimore and Smith, because their study was most recent and because most of their quantitative methods using the electric seine were described in sufficient detail to permit unbiased estimates of abundance, biomass, and species richness to be corrected for gear efficiencies derived in project F-61-R (Bayley and Dowling 1990). We managed to replicate 75 of Larimore and Smith's quantitative samples at the same stations. In addition, we sampled 62 of Larimore and Smith's qualitative stations, of which 28 were quantitative samples. Therefore 137 stations of the 150 sampled by Larimore and Smith were replicated by the present study. Nine of Larimore and Smith's stations on first-order streams were dry and the remainder were not accessible during the present study. Details of our sampling techniques are given elsewhere (Bayley et al. 1989; Bayley and Dowling 1990).

Analyses had to be undertaken to account for the different qualities of sampling among surveys. When comparing all four surveys, we compared total species numbers and presence/absence pooled across samples within surveys. When comparing the past three surveys, proportions of fish numbers comprising each species were also compared.

Further details of samples used for each analysis are given in the analysis in the following section.

Except for larger fish that were processed in the field, fish samples from this study were preserved in 10% formalin to be subsequently sorted, identified, and measured and weighed using an electronic caliper and balance (Bayley and Illyes 1988) in the laboratory. This allowed large quantities of fish to be processed and transferred to computer files and allowed more resources to be concentrated on the accurate identification of species. Preserved subsamples of the fish from each sample were transferred to 70% ethanol and organized as a permanent, ecological collection for future reference.

Current taxonomic knowledge controlled the amount of information to be gained from each survey, and hence from comparisons among them. Table A.1 lists the species names (including some hybrids) and common names, by the species code (originally compiled by Gary Lutterbie) that are shared by the Illinois Department of Conservation (IDOC) and the Illinois Natural History Survey (INHS). Unfortunately this depth of taxonomic information was not known during the first two surveys. A number of identifications that could have been confused in earlier work are designated as 'species pairs' , such as orangethroat and rainbow darters (ORD_RAD), rather than eliminated from the analysis. Many such pairs are expected to have been dominated by one species based on biogeographical information from the past 40-50 years. For example, the central stoneroller is much more common that the largescale stoneroller, which might have occurred in the first two surveys but whose presence in the county has not been verified. Species pairs were treated separately when both species were known and identified, as occurred in the two most recent surveys.

ANALYSIS AND DISCUSSION

Presence/Absence

The lowest level comparison among all four surveys is provided by a presence/absence list of species reported (Table 101.1.1), using information from all samples taken irrespective of replicated samples. Ninety different species are indicated, but not all samples have surviving voucher specimens for verification.

The number of replicated stations within surveys varied, which resulted in large differences between the total number of samples among surveys. This would increase the probability that species would be encountered in surveys with more samples, such as that of Larimore and Smith. Therefore, the analyses for this job only included 462 'unrepeated samples' (i.e., additional samples that were taken at some stations within surveys were excluded). This resulted in comparable numbers of samples among surveys, except for the more limited Forbes and Richardson survey. This is no accident, because the majority of the stations sampled were the same among the past three surveys as described previously. Figures 101.1.1 through 101.1.4 show the locations of the samples in the four surveys. Figure 101.1.5 shows the townships that can be used in conjunction with Table 101.1.2 so that locations of individual samples covered in this report can be identified.

Because of potential confounding of species resulting in 'species pairs', there are 81 independent taxa (species plus species pairs) from unrepeated samples for comparison among all four surveys (Table 101.1.3). Species richness from large numbers of qualitative

Table 101.1.1. Comprehensive list of fish taxa collected and their presence (+) or absence (0) during each of the three previous and the present Fishes of Champaign County studies.

Scientific Name	Common Name	FORBES	THOMPSON	LARIMORE	THIS STUDY
Lepisosteidae					
Lepisosteus osseus	Longnose Gar	0	0	0	+
Lepisosteus platostomus	Shortnose Gar	0	0	0	+
Clupeidae					
Dorosoma cepedianum	Gizzard Shad	+	+	+	+
Hiodon tergisus	Mooneye	0	+	0	0
Esocidae					
Esox americanus	Grass Pickerel	+	+	+	+
Cyprinidae					
Campostoma anomalum	Central Stoneroller	N/A	N/A	+	+
Campostoma anomalum/C. oligolepis	Central/Largescale Stoneroller	+	+	N/A	N/A
Cyprinella lutrensis	Red Shiner	0	0	+	+
Cyprinella lutrensis X C. spiloptera	Red X Spotfin Shiner	0	0	0	+
Cyprinella spiloptera	Spotfin Shiner	N/A	N/A	+	+
Cyprinus carpio	Common Carp	+	+	+	+
Ericymba buccata	Silverjaw Minnow	+	+	+	+
Extrarius aestivalis	Speckled Chub	+	0	0	0
Hybognathus nuchalis	Silvery Minnow	+	+	+	0
Hybopsis amblops	Bigeye Chub	+	+	0	0
Hybopsis dorsalis	Bigmouth Shiner	0	+	+	+
Luxilus chrysocephalus	Striped Shiner	+	+	+	+
Lythrurus umbratilis/Notropis fumeus	Redfin/Ribbon Shiner	+	+	N/A	N/A
Lythrurus umbratilus	Redfin Shiner	N/A	N/A	+	+
Macrhybopsis storeriana	Silver Chub	+	0	0	0
Nocomis biguttatus	Hornyhead Chub	+	+	+	+
Nocomis biguttatus X Notropis chrysocephalus	Hornyhead X Striped Shiner	0	0	0	+
Notemigonus crysoleucas	Golden Shiner	+	+	+	+
Notropis atherinoides	Emerald Shiner	0	+	+	+
Notropis boops	Bigeye Shiner	0	+	0	0
Notropis emiliae (Opsopoeodus emiliae=Page)	Pugnose Minnow	0	+	0	0
Notropis fumeus	Ribbon Shiner	0	0	0	+
Notropis heterolepis/Hybopsis amnis	Blacknose/Pallid Shiner	+	+	0	0
Notropis ludibundus	Sand Shiner	+	+	+	+
Notropis rubellus	Rosyface Shiner	0	0	+	+
Notropis volucellus	Mimic Shiner	0	0	+	0
Notropis whipplei	Steelcolor Shiner	N/A	N/A	+	+
Notropis whipplei/Cyprinella spiloptera	Steelcolor/Spotfin Shiner	+	+	N/A	N/A
Phenacobius mirabilis	Suckermouth Minnow	+	+	+	+
Pimephales notatus	Bluntnose Minnow	+	+	+	+
Pimephales promelas	Fathead Minnow	+	+	+	+
Pimephales vigilax	Bullhead Minnow	+	+	0	0
Semotilus atromaculatus	Creek Chub	+	+	+	+
Catostomidae					
Carpiodes carpio	River Carpsucker	0	0	+	+
Carpiodes spp.	Carpsucker spp.	0	0	+	0

Table 101.1.1. continued.

Scientific Name	Common Name	FORBES	THOMPSON	LARIMORE	THIS STUDY
Carpoides cyprinus	Quillback	+	+	+	+
Carpoides velifer	Highfin Carpsucker	0	+	+	+
Catostomus commersoni	White Sucker	+	+	+	+
Erimyzon oblongus	Creek Chubsucker	+	+	+	+
Hypentelium nigricans	Northern Hogsucker	+	+	+	+
Ictiobus cyprinellus	Bigmouth Buffalo	0	+	0	+
Ictiobus niger	Black Buffalo	0	+	0	0
Minytrema melanops	Spotted sucker	+	+	+	+
Moxostoma anisurum	Silver Redhorse	0	0	+	+
Moxostoma duquesnei	Black redhorse	N/A	N/A	N/A	+
Moxostoma duquesnei/M. erythrurum	Black/Golden Redhorse	+	+	+	N/A
Moxostoma erythrurum	Golden Redhorse	N/A	N/A	N/A	+
Moxostoma macrolepidotum	Shorthead Redhorse	+	+	0	+
Moxostoma spp.	Redhorse spp.	0	0	+	0
Ictaluridae					
Ameiurus melas	Black Bullhead	+	+	+	+
Ameiurus natalis	Yellow Bullhead	+	+	+	+
Ictalurus furcatus	Blue Catfish	+	0	0	0
Ictalurus punctatus	Channel Catfish	+	+	+	+
Noturus exilis	Slender Madtom	0	+	0	0
Noturus flavus	Stonecat	+	+	+	+
Noturus gyrinus	Tadpole Madtom	+	+	+	+
Noturus miurus	Brindled Madtom	+	+	+	+
Noturus nocturnus	Freckled Madtom	0	0	+	+
Pylodictis olivaris	Flathead Catfish	0	0	+	+
Aphredoderidae					
Aphredoderus sayanus	Pirate Perch	0	+	+	+
Fundulidae					
Fundulus notatus	Blackstripe Topminnow	+	+	+	+
Poeciliidae					
Gambusia affinis	Mosquitofish	0	0	+	0
Atherinidae					
Labidesthes sicculus	Brook Silverside	+	+	+	+
Percichthyidae					
Morone chrysops	White Bass	0	0	0	+
Centrarchidae					
Ambloplites rupestris	Rock Bass	0	0	+	+
Lepomis cyanellus	Green Sunfish	+	+	+	+
Lepomis cyanellus X L. megalotis	Green X Longear Sunfish	0	0	0	+
Lepomis gibbosus	Pumpkinseed	+	0	0	0
Lepomis gulosus	Warmouth	+	0	0	0
Lepomis humilis	Orangespotted Sunfish	+	+	+	+
Lepomis macrochirus	Bluegill	+	+	+	+
Lepomis megalotis	Longear Sunfish	+	+	+	+
Lepomis microlophus	Redear Sunfish	0	0	+	+
Micropterus dolomieui	Smallmouth Bass	0	+	+	+

Table 101.1.1. continued.

Scientific Name	Common Name	FORBES	THOMPSON	LARIMORE	THIS STUDY
Micropterus punctulatus	Spotted Bass	N/A	N/A	+	+
Micropterus salmoides	Largemouth Bass	N/A	N/A	+	+
Micropterus salmoides or M. punctulatus	Largemouth/Spotted Bass	+	+	N/A	N/A
Pomoxis annularis	White Crappie	+	+	+	+
Pomoxis nigromaculatus	Black Crappie	+	+	+	+
Percidae					
Ammocrypta pellucida	Eastern Sand Darter	0	+	+	0
Etheostoma asprigene	Mud Darter	+	0	+	+
Etheostoma blennioides	Greenside Darter	+	+	+	+
Etheostoma caeruleum	Rainbow Darter	N/A	N/A	+	+
Etheostoma caeruleum/E. spectabilis	Rainbow/Orangethroat	+	+	N/A	N/A
Etheostoma chlorosomum	Bluntnose Darter	0	+	0	0
Etheostoma flabellare	Fantail Darter	+	+	+	+
Etheostoma gracile/E. exile	Slough/Iowa Darter	0	+	0	0
Etheostoma nigrum	Johnny Darter	+	+	+	+
Etheostoma spectabilis	Orangethroat Darter	N/A	N/A	+	+
Etheostoma zonale	Banded Darter	0	+	+	0
Percina caprodes	Logperch	+	+	+	+
Percina maculata	Blackside Darter	+	+	+	+
Percina phoxocephala	Slenderhead Darter	+	+	+	+
Percina sciera	Dusky Darter	+	0	0	+
Stizostedion vitreum	Walleye	0	0	0	+
Sciaenidae					
Aplodinotus grunniens	Freshwater Drum	0	+	+	+
All sunfish spp. except basses and crappies		0	0	+	0
Unidentified spp.	Unidentified spp.	0	0	+	0

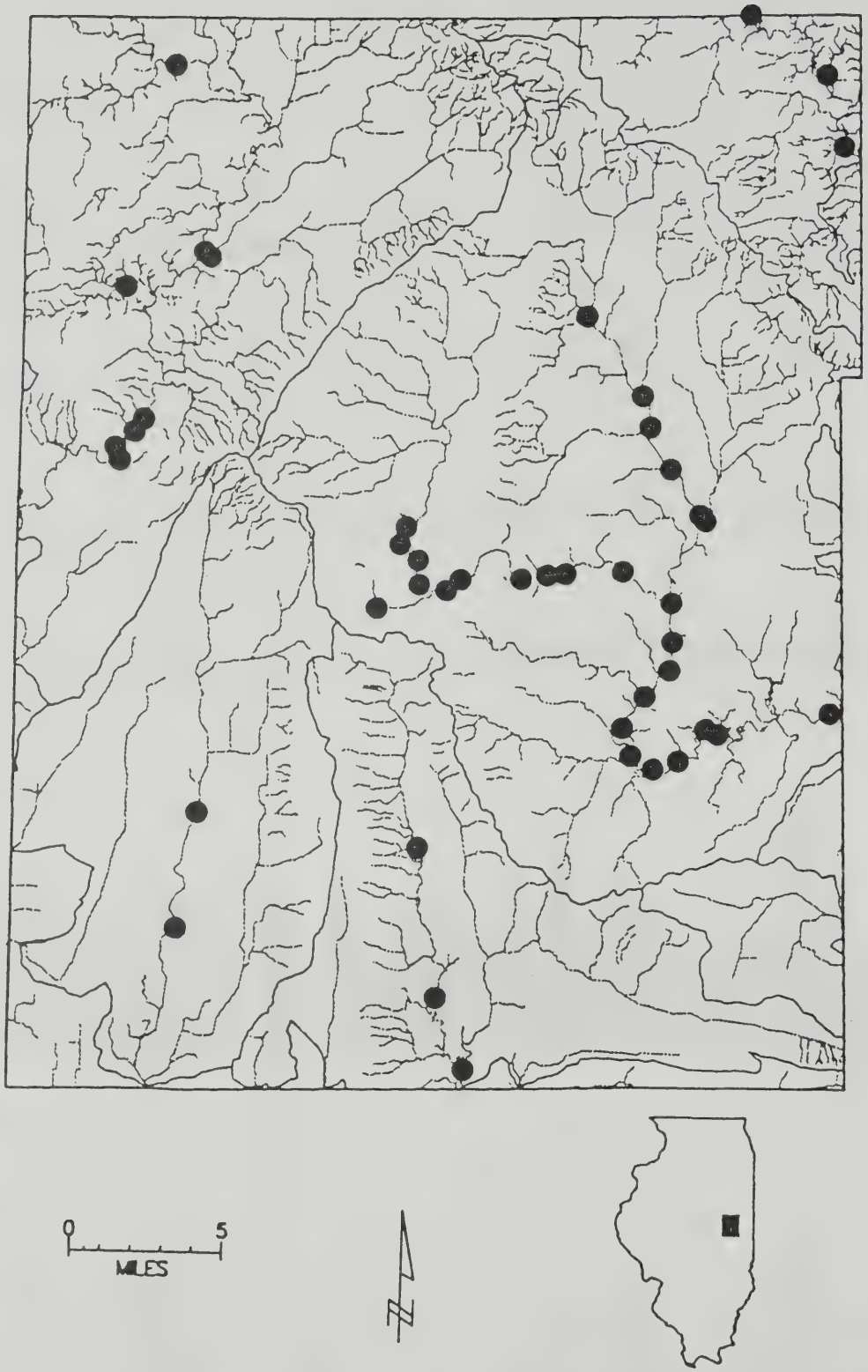


Figure 101.1.1. Location of sampling stations in Champaign County sampled by Forbes and Richardson (1908).

Figure 101.1.2. Location of sampling stations in Champaign County sampled by Thompson and Hunt (1930).

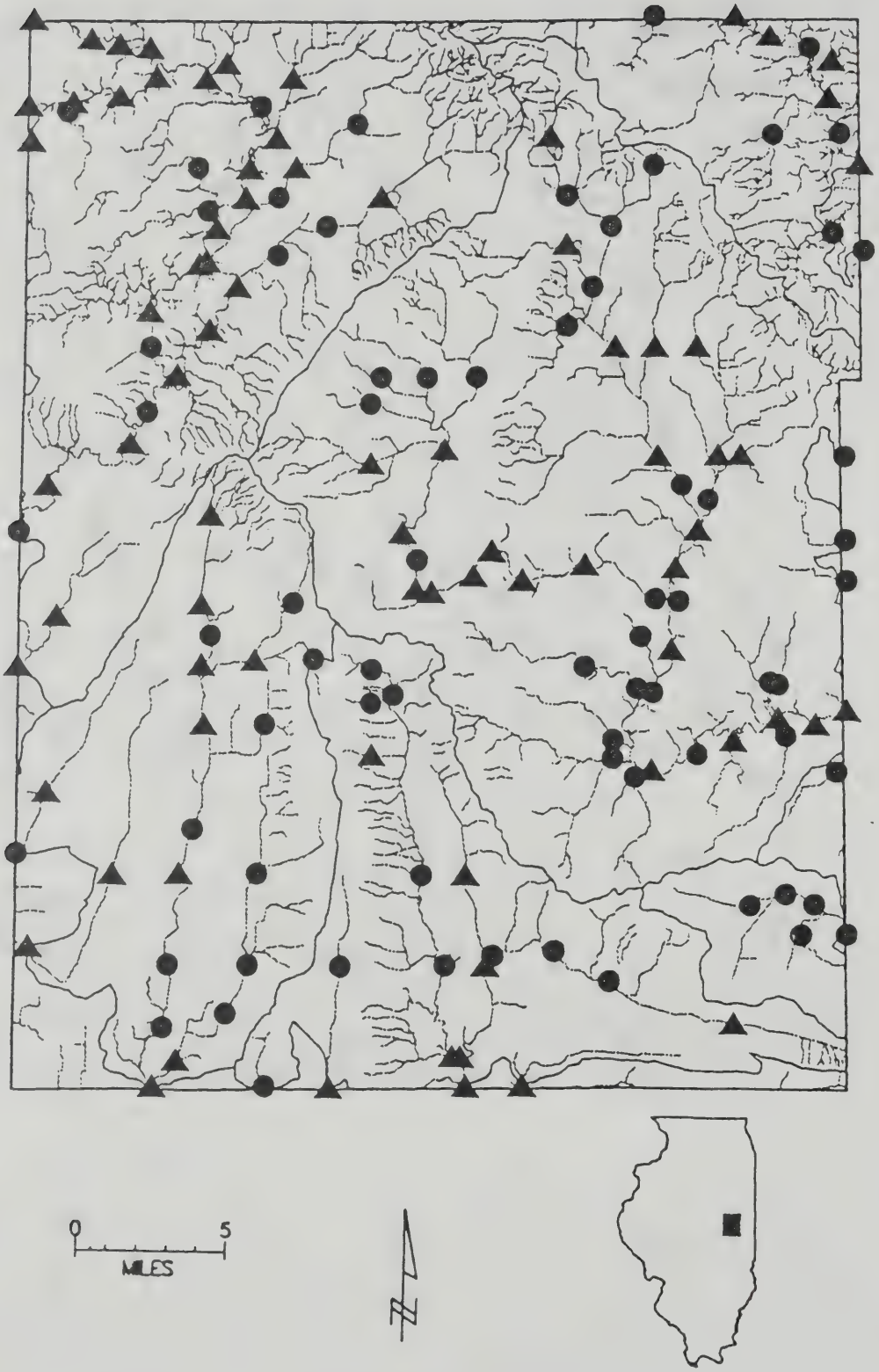


Figure 101.1.3. Location of sampling stations in Champaign County sampled by Larimore and Smith (1963). Circles indicate qualitative samples made with minnow-seine. Triangles indicate quantitative samples made with electric-seine.

Figure 101.1.4. Location of sampling stations in Champaign County sampled in the present study. Circles indicate qualitative samples made with minnow-seine. Triangles indicate quantitative samples made with electric-seine.

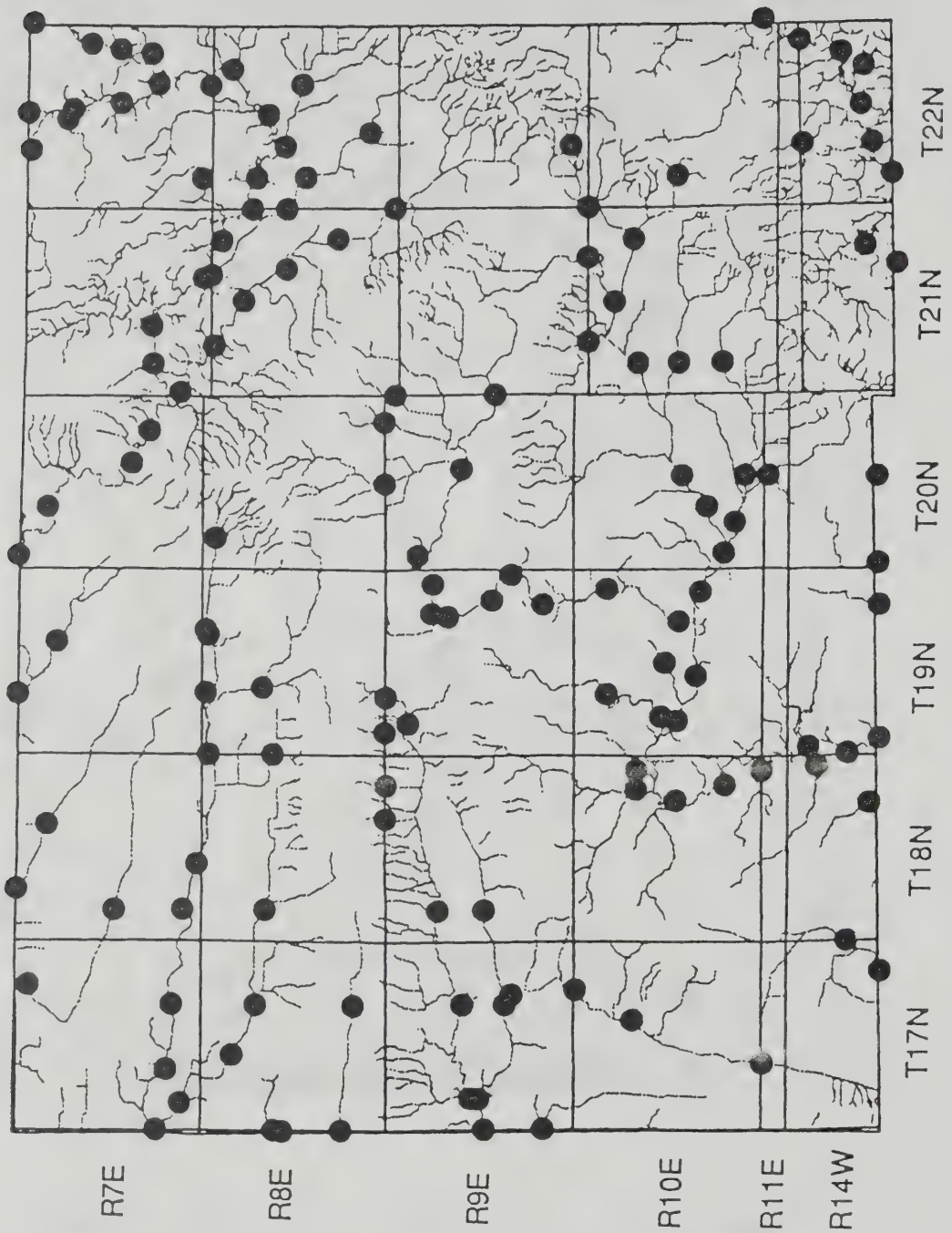


Figure 101.1.5. Locations of all sampling stations (historical and modern) in Champaign County. Also shown is corresponding township-range scale to facilitate identifying location.

Table 101.1.2. Fish sampling numbers and their associated geographic coordinates.

Station	Township	Range	Section	
JORD-2001	19N	13W	27	NE1/4
JORD-2002	19N	13W	27	SW1/4
JORD-2005	19N	13W	33	NE1/4
JORD-2006	19N	13W	33	N1/2
JORD-2008	18N	13W	4	NW1/4
JORD-2010	18N	13W	4	NW1/4
JORD-2010	18N	13W	4	NW1/4
JORD-2011	18N	13W	4	NW1/4
JORD-2015	18N	13W	4	NW1/4
JORD-2017	18N	13W	4	NW1/4
JORD-2020	18N	13W	4	W1/2
JORD-2022	18N	13W	5	E1/2
JORD-2023	18N	13W	5	SE1/4
JORD-2024	18N	13W	5	SE1/4
JORD-2025	18N	13W	9	SW1/4
JORD-2026	18N	13W	9	S1/2
JORD-2027	18N	13W	16	N1/2
LARC-1023	19N	9E	31	NE1/4
LARC-1024	19N	8E	36	NE1/4
LARC-1025	18N	8E	1	SE1/4
LARC-1026	18N	8E	13	NE1/4
LARC-1027	19N	8E	25	NE1/4
LARC-1028	18N	9E	29	S1/2
LARC-1029	18N	9E	27	SW1/4
LARC-1030	17N	9E	9	SW1/4
LARC-1031	17N	9E	10	S1/2
LARC-1032	17N	9E	12	E1/2
LARC-1033	17N	9E	34	SW1/4
LARC-1034	17N	9E	34	NW1/4
LARC-1035	17N	9E	28	SE1/4
LARC-1037	19N	14W	31	SE1/4
LARC-1040	19N	9E	3	SW1/4
LARC-1041	19N	9E	3	NE1/4
LARC-1042	19N	9E	11	NE1/4
LARC-1043	19N	9E	8	NW1/4
LARC-1044	19N	9E	9	NW1/4
LARC-1092	20N	9E	16	SW1/4
LARC-1093	20N	9E	32	NW1/4
LARC-1095	20N	8E	24	NE1/4
LARC-1096	20N	8E	12	NE1/4
LARC-1097	21N	10E	28	SE1/4
LARC-1099	21N	9E	34	SW1/4
LARC-1100	21N	9E	25	NE1/4
LARC-1102	21N	10E	7	W1/2
LARC-1106	20N	8E	30	S1/2
LARC-1107	19N	8E	7	SW1/4
LARC-1108	19N	8E	19	SW1/4
LARC-1109	19N	8E	31	SW1/4
LARC-1110	18N	7E	25	SW1/4

Table 101.1.2. continued

Station	Township	Range	Section	
LARC-1112	17N	8E	11	SE1/4
LARC-1113	17N	8E	35	S1/2
LARC-1114	16N	8E	4	NE1/4
LARC-1115	17N	8E	33	SW1/4
LARC-1116	17N	7E	36	NW1/4
LARC-1117	17N	7E	35	S1/2
LARC-1118	18N	8E	28	SW1/4
LARC-1120	21N	7E	35	SE1/4
LARC-1121	19N	7E	17	NW1/4
LARC-1122	19N	7E	30	SW1/4
LARC-1123	18N	7E	17	NW1/4
LARC-1124	17N	7E	7	NW1/4
LARC-1125	18N	7E	27	SW1/4
LARC-1128	19N	10E	2	SW1/4
LARC-1129	20N	10E	35	NE1/4
LARC-1130	19N	8E	33	SW1/4
LARC-1131	19N	8E	21	SW1/4
LARC-1134	17N	14W	4	SE1/4
LARC-1138	17N	9E	24	SE1/4
LARC-1139	17N	9E	36	SW1/4
LARC-1140	17N	9E	34	SW1/4
LARC-1141	19N	14W	33	E1/2
LARC-1142	22N	9E	36	SE1/4
LARC-1143	22N	9E	24	S1/2
LARC-1145	22N	10E	1	N1/2
LARC-1146	22N	10E	1	E1/2
LARC-1147	22N	11E	25	NE1/4
LARC-1148	22N	10E	28	SE1/4
LARC-1149	22N	8E	21	SW1/4
LARC-1150	19N	14W	9	NE1/4
LARC-1151	20N	14W	33	SE1/4
LARC-1152	20N	14W	16	SE1/4
LARC-1154	21N	14W	9	SE1/4
LARC-1155	21N	14W	8	NE1/4
LARC-1156	22N	14W	28	SE1/4
LARC-1157	22N	14W	9	NW1/4
LARC-1158	22N	14W	17	SE1/4
LARC-1159	22N	8E	29	SW1/4
LARC-1160	22N	8E	32	SW1/4
LARC-1161	21N	8E	6	SW1/4
LARC-1162	22N	7E	30	NW1/4
LARC-1163	22N	6E	13	SE1/4
LARC-1164	22N	7E	17	S1/2
LARC-1165	22N	7E	20	NW1/4
LARC-1166	22N	7E	16	E1/2
LARC-1167	22N	7E	11	SW1/4
LARC-1168	22N	7E	5	SE1/4
LARC-1169	23N	7E	31	SW1/4
LARC-1170	22N	7E	5	SE1/4
LARC-1171	22N	7E	3	SE1/4

Table 101.1.2 continued.

Station	Township	Range	Section	
LARC-1172	22N	7E	25	SE1/4
LARC-1174	21N	8E	18	NW1/4
LARC-1175	21N	8E	30	NW1/4
LARC-1176	21N	7E	13	NE1/4
LARC-1177	21N	7E	23	SW1/4
LARC-1178	19N	10E	16	SE1/4
LARC-1179	22N	8E	17	SW1/4
LARC-1180	22N	7E	12	SE1/4
LARC-1181	22N	8E	7	E1/2
LARC-1182	22N	8E	9	SE1/4
LARC-1183	22N	8E	27	SW1/4
LARC-1184	22N	8E	36	SE1/4
LARC-1185	19N	9E	30	NE1/4
LARC-1186	19N	10E	28	SE1/4
LARC-1187	18N	10E	5	E1/2
LARC-1188	18N	10E	8	NE1/4
LARC-1190	18N	14W	5	NW1/4
LARC-1193	19N	14W	32	SE1/4
LARC-1194	20N	7E	15	NE1/4
LARC-1195	20N	7E	20	SW1/4
LARC-1196	21N	10E	29	S1/2
LARC-1197	21N	10E	28	SE1/4
LARC-1198	21N	10E	26	SW1/4
LARC-1199	20N	14W	18	SW1/4
LARC-1200	20N	10E	13	S1/2
LARC-1201	20N	10E	15	SW1/4
LARC-1203	19N	10E	6	SE1/4
LARC-1205	19N	10E	22	NE1/4
LARC-1206	19N	10E	27	S1/2
LARC-1207	18N	10E	10	W1/2
LARC-1208	18N	10E	1	E1/2
SCUM-1603	20N	9E	7	E1/2
SCUM-1604	20N	9E	7	E1/2
SCUM-1605	20N	9E	8	SE1/4
SCUM-1605	20N	9E	8	SE1/4
SCUM-1606	20N	9E	8	SE1/4
SCUM-1606	20N	9E	8	SE1/4
SCUM-1608	20N	9E	16	N1/2
SCUM-1609	20N	9E	16	N1/2
SUGR-1702	22N	14W	9	N1/2
SUGR-1703	22N	14W	9	N1/2
SUGR-1704	22N	14W	9	NW1/4
SUGR-1705	22N	14W	9	NW1/4
SUGR-1709	22N	14W	8	SE1/4
SUGR-1709	22N	14W	8	E1/2
SUGR-1710	22N	14W	8	E1/2
SUGR-1711	22N	14W	8	E1/2
SUGR-1712	22N	14W	8	SE1/4
SUGR-1713	22N	14W	8	SE1/4
SUGR-1714	22N	14W	8	SE1/4

Table 101.1.2 continued

Station	Township	Range	Section	
SUGR-1715	22N	14W	17	NE1/4
SUPP-1501	22N	8E	24	NW1/4
SUPP-1502	22N	8E	33	SW1/4
SUPP-1503	21N	8E	3	SE1/4
SUPP-1504	21N	8E	9	SW1/4
SUPP-1505	21N	7E	27	S1/2
SUPP-1506	20N	7E	15	NE1/4
SUPP-1507	20N	7E	31	W1/2
SUPP-1508	18N	7E	30	NW1/4
SUPP-1509B	19N	8E	18	NW1/4
SUPP-1510	18N	8E	7	SW1/4
SUPP-1511	17N	7E	12	SW1/4
SUPP-1512	17N	8E	8	SE1/4
SUPP-1513	17N	7E	23	SE1/4
SUPP-1514	17N	8E	20	W1/2
SUPP-1515	17N	9E	11	W1/2
SUPP-1516	17N	10E	17	SE1/4
SUPP-1517	18N	14W	32	SE1/4
SUPP-1518	18N	14W	9	E1/2
SUPP-1519	18N	10E	11	NE1/4
SUPP-1520	19N	10E	10	SW1/4
SUPP-1522	21N	10E	18	S1/2
SUPP-1523	21N	10E	5	S1/2
SUPP-1524	22N	14W	21	SW1/4
SUPP-1525	20N	10E	26	W1/2
SUPP-1526	20N	10E	25	W1/2
SUPP-1527	22N	14W	5	SW1/4
SUPP-1528	22N	8E	17	SE1/4
SUPP-1529	19N	9E	5	N1/2

Table 101.1.3. Frequencies of samples (non-replicated within surveys) containing species or species pairs (81 taxa from 461 samples). (See Table A.1 for species code identifucations.)

Species Code	Survey: (# samples) Forbes (46)	Thompson (125)	Larimore (150)	1987/88 (140)	Total (461)
BAD	0	8	3	0	11
BCF	1	0	0	0	1
BGB	0	0	0	2	2
BGC	4	7	0	0	11
BGS	0	2	0	0	2
BKB	0	1	0	0	1
BLB	11	12	4	17	44
BLC	4	2	0	2	8
BLD	14	23	44	13	94
BLG	1	1	10	44	56
BLR_GOR	7	20	49	32	108
BLS	38	105	123	112	378
BLT	14	40	50	98	202
BMS	0	5	26	18	49
BNS_PLS	1	1	0	0	2
BRM	6	0	5	6	17
BRS	6	2	1	2	11
BUD	0	1	0	0	1
BUM	4	3	0	0	7
CAP	5	8	49	34	96
CCF	4	7	13	12	36
CCS	21	44	76	59	200
COS_LSS	19	63	94	75	251
CRC	9	99	121	94	323
DUD	1	0	0	3	4
EMS	0	3	0	0	3
ESD	0	2	1	0	3
FAD	4	13	15	1	33
FCF	0	0	3	2	5
FHM	3	20	18	4	45
FRD	0	3	1	13	17
FRM	0	0	0	5	5
GOS	20	39	39	11	109
GRD	9	8	13	3	33
GRP	5	24	14	58	101
GSF	25	36	69	83	213
GZS	1	0	8	23	32
HFC	0	4	29	11	44
HOC	10	46	64	57	177
JOD	23	80	74	42	219
LMB_SPB	4	3	19	35	61
LOP	1	2	6	3	12
LOS	17	36	50	101	204
MMS	0	0	3	0	3
MOF	0	0	2	0	2

Table 101.1.3. continued.

Species Code	Forbes (46)	Thompson (125)	Larimore (150)	1987/88 (140)	Total (461)
		Survey: (# samples)			
MUD	2	0	1	1	4
NHS	6	26	39	28	99
ORD_RAD	7	32	59	37	135
ORS	14	13	6	8	41
PRP	0	12	11	12	35
PUM	0	1	0	0	1
RBS_RDS	9	66	88	67	230
RES	0	0	15	13	28
ROB	0	0	15	15	30
RSF	0	0	1	3	4
RVC	0	0	0	5	5
RYS	0	0	6	0	6
SAS	23	44	77	76	220
SDS	14	3	1	9	27
SES_SFS	32	52	58	79	221
SHD	2	7	16	3	28
SHG	0	0	0	1	1
SHR	4	4	0	10	18
SJM	22	75	67	48	212
SLD_OWD	0	1	0	0	1
SLM	0	3	0	0	3
SMB	0	16	36	28	80
SPC	1	0	0	0	1
STC	1	5	17	12	35
STS	9	55	81	113	258
SUM	16	23	28	23	90
SVC	1	0	0	0	1
SVM	4	9	8	0	21
SVR	0	0	3	11	14
TPM	11	7	18	30	66
ULL	10	9	45	33	97
WAM	1	0	0	0	1
WHB	0	0	0	7	7
WHC	2	2	9	8	21
WHS	16	62	47	41	166
YEB	7	14	30	10	61

samples can be expected to reflect overall changes in the fish assemblage, in particular if the environment has been degraded. Table 101.1.4 shows the accumulated species richness values (total number of species or species pairs) from unrepeated samples. Except for the poorly sampled first survey, there is remarkable consistency among species richness. Only two species, common carp and redear sunfish, have been introduced, and carp was present in all four surveys. The apparent consistency in the richness measure belies the changes that have occurred in individual species and the fish assemblages, as described below.

Table 101.1.4. Accumulated species richness values from non-replicated samples within surveys, from a total of 81 species or species pairs.

	Forbes	Thompson	Larimore	1987/88
Total	55	60	59	61
Introduced spp.	1	1	2	2
Indigenous spp.	54	59	57	59

Presence/absence maps are shown in Figures A.1 through A.67 (Appendix A) for selected species of interest, using data from unrepeated samples. Although a few of the presence/absence maps indicate obvious changes, such as the increase of the blackstripe topminnow or the decrease of golden shiner, it is difficult to assess significant changes of many species visually. Individual species changes are analyzed below, following an assemblage comparison.

Has the fish assemblage changed? How do we compare community structure? Similarity indices can be useful for deriving similar groups of communities or stations, but currently methods are not available for differences to be tested statistically. Two-way tables of frequencies can be tested. The validity of these tests depends, among other factors, on having sufficient counts among cells. For analyses that include the qualitative data of the first two surveys, two measures of assemblages were used. First, the distribution of species among samples was compared. Second, the distribution of numbers of fish among species of samples pooled within surveys was compared. The second comparison could not include the first survey, because numbers of fish for all species could not be deciphered from Forbes and Richardson's data.

In the first comparison, a subset of 47 species (including 6 species pairs) provided sufficient expected cell frequencies in a two-way table (Table 101.1.5) for a chi-squared test. The chi-squared test was highly significant ($p<.00001$) indicating that the distributions of species among samples was different among the four surveys. A more rigorous test which only included 15 species that occurred in at least 10 unrepeated samples from each survey was also highly significant ($p<0.000001$). Highly significant differences in the distribution of species among samples was also found when the less-extensive Forbes and Richardson data were excluded.

Table 101.1.5 Percentage distribution of samples (non-replicated within surveys) with species that occurred in five or more samples from two or more surveys. (The numbers shown are the percentages of the total number of samples collected during each survey in which each taxon occurred.

	Forbes	Thompson	Larimore	1987/88	Mean %	# occurrences
BLB	2.32	0.95	0.22	0.98	0.83	44
BLD	2.95	1.81	2.38	0.75	1.76	94
BLG	0.21	0.08	0.54	2.53	1.05	56
BLR_GOR	1.47	1.58	2.65	1.84	2.03	108
BLS	8.00	8.28	6.66	6.45	7.10	378
BLT	2.95	3.15	2.71	5.65	3.79	202
BMS	0.00	0.39	1.41	1.04	0.92	49
BRM	1.26	0.00	0.27	0.35	0.32	17
CAP	1.05	0.63	2.65	1.96	1.80	96
CCF	0.84	0.55	0.70	0.69	0.68	36
CCS	4.42	3.47	4.11	3.40	3.76	200
COS_LSS	4.00	4.97	5.09	4.32	4.71	251
CRC	1.89	7.81	6.55	5.41	6.06	323
FAD	0.84	1.03	0.81	0.06	0.62	33
FHM	0.63	1.58	0.97	0.23	0.84	45
GOS	4.21	3.08	2.11	0.63	2.05	109
GRD	1.89	0.63	0.70	0.17	0.62	33
GRP	1.05	1.89	0.76	3.34	1.90	101
GSF	5.26	2.84	3.74	4.78	4.00	213
GZS	0.21	0.00	0.43	1.32	0.60	32
HFC	0.00	0.32	1.57	0.63	0.83	44
HOC	2.11	3.63	3.47	3.28	3.32	177
JOD	4.84	6.31	4.01	2.42	4.11	219
LMB_SPB	0.84	0.24	1.03	2.02	1.15	61
LOS	3.58	2.84	2.71	5.82	3.83	204
NHS	1.26	2.05	2.11	1.61	1.86	99
ORD_RAD	1.47	2.52	3.19	2.13	2.53	135
ORS	2.95	1.03	0.32	0.46	0.77	41
PRP	0.00	0.95	0.60	0.69	0.66	35
RBS_RDS	1.89	5.21	4.76	3.86	4.32	230
RES	0.00	0.00	0.81	0.75	0.53	28
ROB	0.00	0.00	0.81	0.86	0.56	30
SAS	4.84	3.47	4.17	4.38	4.13	220
SDS	2.95	0.24	0.05	0.52	0.51	27
SES_SFS	6.74	4.10	3.14	4.55	4.15	221
SHD	0.42	0.55	0.87	0.17	0.53	28
SJM	4.63	5.91	3.63	2.76	3.98	212
SMB	0.00	1.26	1.95	1.61	1.50	80
STC	0.21	0.39	0.92	0.69	0.66	35
STS	1.89	4.34	4.39	6.51	4.84	258
SUM	3.37	1.81	1.52	1.32	1.69	90
SVM	0.84	0.71	0.43	0.00	0.39	21
TPM	2.32	0.55	0.97	1.73	1.24	66
ULL	2.11	0.71	2.44	1.90	1.82	97
WHC	0.42	0.16	0.49	0.46	0.39	21
WHS	3.37	4.89	2.54	2.36	3.12	166
YEB	1.47	1.10	1.62	0.58	1.15	61

The foregoing presence/absence comparison does not account for differences in comparison, differences were highly significant ($p<0.0000001$) with the 47 species and with the more rigorous test with the 15 most common species.

Which species are most influential in these assemblage differences? One can make guesses by looking at the presence/absence maps, or preferably use appropriate statistical tests as a guide. Separate, two-way tables of presence/absence frequencies among unrepeated samples by survey were analyzed for each of the 47 species (Table 101.1.6). Because these are multiple tests, a more conservative estimate of significance was determined by Bonferroni-adjusted probabilities. Table 101.1.6 shows comparisons among all four surveys and the past three. Many species indicate no changes with either comparison. Although, somewhat surprisingly, Forbes and Richardson reported no smallmouth bass, the past three surveys revealed no significant change (although biomass changed since 1959 as will be shown below).

Species that indicated general increases in percentage occurrence through time include blackstripe topminnow, bluegill, common carp, grass pickerel, green sunfish, largemouth/spotted bass, longear sunfish, striped shiner, and quillback. General decreases were observed in blackside darter, golden shiner, johnny darter, and silverjaw minnow. Other significant results reflected more complex changes through time. Non-significance does not rule out a change during part of the time series. For example, the silvery minnow was not uncommon during the first three surveys, but none was found in the present survey.

Quantitative comparisons between 1959 and this study

Results from 75 stations that were sampled by the 30-ft electric seine and documented sufficiently for efficiency corrections in 1959 were compared with samples from the current study from the same stations. Efficiency corrections were made according to the formulae derived from the F-61-R project (Bayley and Dowling 1990). That project indicated that although the capture efficiency for darters tended to be higher with the electric seine than for other non-rotenone gears, it was still low, averaging about 2%. The current efficiency formula for darters predicted a few unrealistically high population values. Until the efficiency data are reanalyzed, the comparisons of abundance and biomass densities, such as those in this report, will exclude darters. This omission will have a negligible effect on prey fish estimates, because darters are a very small component of the piscivore diets analyzed in this project.

Abundance and biomass were compared on a per-unit-stream-length basis, so that short-term discharge differences that affect fish quantities per unit area would be avoided. An overall difference in discharge between 1959 and 1987/88 was not apparent from the t-paired comparison of cross sectional area which was not significant ($P=.125$, Table 101.1.7). It should be noted that two of the 75 replicates were taken in the drought year of 1988, but that these were in the lower Salt Fork that was not directly affected (see study 102).

Table 101.1.7 summarizes results from t-paired analyses of the 75 paired sites. Species richness and prey quantities did not change, but total biomass increased significantly. This is partly explained by the overall biomass increase in the six large predator species. Although some increases were not significant, the sign test of all six species was positive at $P=0.03$. Grass pickerel, channel catfish, and smallmouth bass had the most significant increases in biomass. Increases in numbers were often not significant, implying that conditions had improved for larger individuals. A plot of the individual sample values

Table 101.1.6. Tests of association between all four surveys and the past three surveys on species occurrence using 2-way tables of presence/absence. Shown are percentages of numbers of samples, non-replicated within surveys, in which each species was encountered. The 47 species or species pairs shown occurred in five or more samples in two or more surveys. (These are multiple tests, consequently Bonferroni-adjusted probabilities were assigned to each Chi-squared estimate to provide the following significance: * = .05, ** = .01, *** = .001).

SURVEY:	Forbes	Thompson	Larimore	1987/88	ALL 4 SURVEYS			PAST 3 SURVEYS		
(#SAMPLES)	(46)	(125)	(150)	(140)	CHI^2	P		CHI^2	P	
SPECIES										
BLB	24.0	9.6	2.7	12.1	20.0	0.000139	**	9.6	0.008430	
BLD	30.4	18.4	29.1	9.2	21.2	0.000096	**	18.7	0.000086	**
BLG	2.2	0.8	6.6	31.2	71.9	0.000000	***	62.4	0.000000	***
BLR_GOR	15.2	16.0	32.5	22.7	12.5	0.005846		10.4	0. 005647	
BLS	82.6	84.0	81.5	79.4	1.0	0.812126		0.9	0. 631587	
BLT	30.4	32.0	33.1	69.5	55.3	0.000000	***	51.3	0. 000000	***
BMS	0.0	4.0	17.2	12.8	18.9	0.000286	*	11.7	0. 002830	
BRM	13.0	0.0	3.3	4.3	16.4	0.000948	*	5.1	0.078492	
CAP	10.9	6.4	32.5	24.1	31.9	0.000001	***	27.9	0.000001	***
CCF	8.7	5.6	8.6	8.5	1.1	0.769361		1.1	0.581398	
CCS	45.7	35.2	50.3	41.8	6.6	0.085491		6.5	0. 038917	
COS_LSS	41.3	50.4	62.2	53.2	7.8	0.050099		4.4	0. 110398	
CRC	19.6	79.2	80.1	66.7	68.6	0.000000	***	8.6	0. 013784	
FAD	8.7	10.4	9.9	0.7	12.8	0.005175		12.9	0.001610	
FHM	6.5	16.0	11.9	2.8	14.6	0.002191		13.6	0.001132	
GOS	43.5	31.2	25.8	7.8	34.1	0.000000	***	24.4	0.000005	***
GRD	19.6	6.4	8.6	2.1	16.7	0.000824	*	5.8	0.055461	
GRP	10.9	19.2	9.3	41.1	48.5	0.000000	***	43.2	0.000000	***
GSF	54.3	28.8	45.7	58.9	25.6	0.000012	***	24.2	0.000005	***
GZS	2.2	0.0	5.3	16.3	30.9	0.000001	***	27.2	0.000001	***
HFC	0.0	3.2	19.2	7.8	27.6	0.000004	***	20.3	0.000040	**
HOC	21.7	36.8	42.4	40.4	6.8	0.078658		0.9	0.637364	
JOD	50.0	64.0	49.0	29.8	31.6	0.000001	***	31.5	0.000000	***
LMB_SPB	8.7	2.4	12.6	24.8	30.3	0.000001	***	28.5	0.000001	***
LOS	37.0	28.8	33.1	71.6	63.6	0.000000	***	62.3	0. 000000	***
NHS	13.0	20.8	25.8	19.9	3.9	0.272685		1.7	0.420633	
ORD_RAD	15.2	25.6	39.1	26.2	12.9	0.004947		7.8	0.020019	
ORS	30.4	10.4	4.0	5.7	33.1	0.000000	***	4.9	0.086732	
PRP	0.0	9.6	7.3	8.5	4.7	0.194683		0.5	0.786398	
RBS_RDS	19.6	52.8	58.3	47.5	21.9	0.000068	**	3.4	0.183417	
RES	0.0	0.0	9.9	9.2	17.5	0.000553	*	12.9	0.001574	
ROB	0.0	0.0	9.9	10.6	18.8	0.000294	*	13.9	0.000962	*
SAS	50.0	35.2	51.0	53.9	10.8	0.013135		10.6	0.004909	
SDS	30.4	2.4	0.7	6.4	60.8	0.000000	***	8.2	0.016532	
SES_SFS	69.6	41.6	38.4	56.0	19.8	0.000185	**	10.1	0.006310	
SHD	4.3	5.6	10.6	2.1	9.6	0.022400		9.1	0.010742	
SJM	47.8	60.0	44.4	34.0	18.2	0.000399	*	18.1	0.000115	**
SMB	0.0	12.8	23.8	19.9	16.6	0.000867	*	5.4	0.065892	
STC	2.2	4.0	11.3	8.5	7.3	0.062521		4.8	0.088596	
STS	19.6	44.0	53.6	80.1	65.7	0.000000	***	39.6	0.000000	***
SUM	34.8	18.4	18.5	16.3	8.0	0.046857		0.3	0.860291	
SVM	8.7	7.2	5.3	0.0	10.8	0.012919		9.7	0.007881	
TPM	23.9	5.6	11.9	21.3	17.5	0.000549	*	14.6	0.000691	*
ULL	21.7	7.2	29.8	23.4	21.9	0.000067	**	22.0	0.000017	***
WHC	4.3	1.6	6.0	5.7	3.6	0.305373		3.6	0.165181	
WHS	34.8	49.6	31.1	29.1	14.6	0.002218		14.5	0.000700	*
YEB	15.2	11.2	19.9	7.1	11.1	0.011368		11.0	0.004003	

Table 101.1.7. T-pair comparisons between 75 replicated Fishes of Champaign County sites of current study and those of Larimore and Smith (positive t-value indicates mean of 1987/88 samples higher than 1959).

ITEM	T-PAIR	DF	P[1]
cross-section area	1.551	74	0.125
Estimated richness	0.127	74	0.900
Measured richness	0.533	74	0.595
Prey numbers	-1.006	73	0.318
Prey biomass	0.852	73	0.397
Total numbers (less darters)	-1.448	73	0.152
Total biomass (less darters)	2.335	73	0.022*
Large predator species:			
SMB numbers	1.273	74	0.207
SMB biomass	3.289	74	0.002*
SPB numbers	-1.001	74	0.320
SPB biomass	2.058	74	0.043
LMB numbers	0.902	74	0.370
LMB biomass	1.840	74	0.070
ROB numbers	0.888	74	0.377
ROB biomass	1.693	74	0.095
CCF numbers	2.285	74	0.025
CCF biomass	2.884	74	0.005*
GRP numbers	3.276	74	0.002*
GRP biomass	6.186	74	0.000**

* significance at P=.05, ** significance at P=.01. Six predators adjusted for Bonferroni significance levels (i.e., significance at .05 level requires P < .05/6).

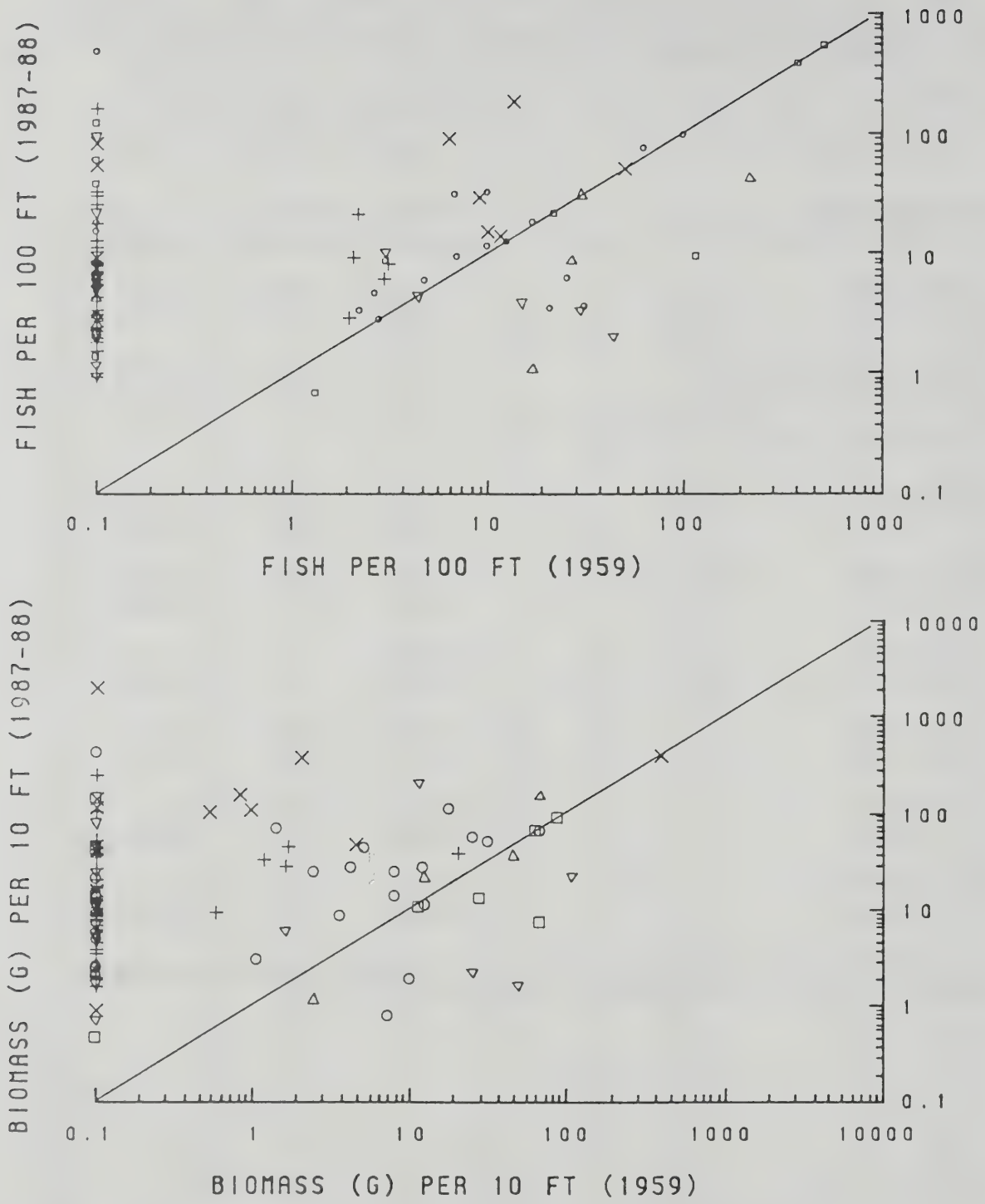


Figure 101.1.6 Comparisons of numbers and biomass per length of stream for 6 large predator species between present study and Larimore and Smith (1963) for 75 replicated sites (see Table 101.1.7). (0.1 = no fish caught; samples in which neither survey caught fish not plotted; line indicates equal quantities)

reveals another feature (Fig. 101.1.6): a large number of samples yielded individuals where none had been found in 1959, whereas the converse situation was never encountered.

This comparison does not prove that the condition of Champaign county streams is now satisfactory. The densities of sportfish, which comprise most of the large predators, are low compared with less impacted streams in Illinois, including some in the same stream networks. There have not been major changes in land-use or "drainage improvement" practices during the past 30 years (see later section), but there is evidence of an improvement in water quality. The field notes of Larimore and Smith are replete with comments about visible effects of pollution, such as "badly polluted, severe odor, sludge on bottom"; "stinking, thick running mess". One station was not even approached because the odor was so repulsive. Although pollution events do occur periodically and subtle, chronic pollution effects are suspected, none of these comments are appropriate descriptions for the environments we encountered. Also, many townships have made some improvements in raw sewage treatment since the 1950's, although full compliance with the Clean Water Act has still not been achieved.

This preliminary analysis suggests that the sportfish species were primarily limited by poor water quality in the 1950's. We consider that their current, higher densities are limited by other man-induced factors, which are considered in the following sections.

JOB 101.2 LAND-USE AND HABITAT

INTRODUCTION

The importance of physical habitat to the structure and composition of stream communities is well established (Hynes 1970). A fundamental characteristic of all streams is the capacity to integrate watershed patterns and processes (Wiley et al. 1990). Thus, land-use and cultural modifications occurring within a watershed ultimately influence the quality of the stream environment and fish habitat condition.

Larimore and Smith (1963) alluded to the general changes in land use that occurred in Champaign County during the preceding 60 years. Prior to 1960, the principal changes included increases in urbanization and industrialization and decreases in forested and undrained lands. These changes were similar to other watersheds in the state during this same period. Technological limitations prevented earlier investigators (Forbes and Richardson 1908, Thompson and Hunt 1930, and Larimore and Smith 1963) from quantitatively assessing land-use and cultural watershed modifications on instream habitat. The recent advent of computer-based geographical information systems (GIS) has provided researchers with the capabilities of accurately and rapidly addressing land-use and cover patterns. Documenting such changes in land-use and comparing them to qualitative changes in fish community composition and structure will provide valuable insights into the influence of landscape modifications on fish community structure.

More subtle sociological changes have also been instituted during the past 30 years including passage of more stringent laws (e.g., Toxic Substance Control Act, Clean Water Act), advances and implementation of municipal waste treatment, reduction or elimination of the use of persistent chloro-organic pesticides, constraints on the degree and extent of permissible channel modifications, and an apparent increase in the implementation of conservation farming practices that may reduce sediment loading to streams. While there have been obvious changes in cultural practices there has unfortunately been inadequate quantification of instream habitat conditions during the previous sampling programs. This lack of historical data does not permit a valid assessment and determination of any general change in instream habitat conditions to be made. Therefore, a primary objective of this study was to quantify local instream habitat conditions at several fish sampling stations and to relate these data to fish community structure in an attempt to identify environmental variables controlling the structure of stream fish communities. This will also serve as a basis for comparison in future studies.

Land use and land cover patterns for Champaign County were interpreted and analyzed for two time periods to provide insight into changes that have occurred in the study area since the Larimore and Smith (1963) study. These time periods, late 1950's (referred to throughout text as historical) and mid-1980's (referred to throughout text as modern) approximate the period that fish sampling (Larimore and Smith 1963, and present study) was conducted. Sources of information and methods of data acquisition necessarily differed because of limited availability of historical information and a limited budget. Nonetheless, these datasets represent one of the few instances where detailed historical and modern day land use information have been analyzed and related to fish communities and changes in sportfish populations.

METHODS

General Land Use

To achieve the fundamental goals of this study we quantified land use conditions during the 1980's for the six major drainage basins in Champaign County. Hydrology and watershed boundaries for each sampling station (Figure 101.2.1) were determined by interpreting recent 7.5-min. (1:24,000) USGS topographic maps. Hydrology information was taken from a statewide stream network created from 1981 aerial photos and edited to correspond to stream traces found on 7.5-min. maps.

Table 101.2.1. The percent of each major land use category (LUDA level I) and the total acres of land in each station watershed based on modern (1988) map interpretation.

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1023	3,977.98	51.03	47.95	0.63	0.39	0.00
1024	460.17	19.51	79.20	0.00	1.29	0.00
1025	491.80	32.52	66.43	0.90	0.15	0.00
1026	305.67	0.00	100.00	0.00	0.00	0.00
1027	1,220.00	65.40	33.80	0.36	0.44	0.00
1028	17,481.47	16.14	83.52	0.20	0.15	0.00
1029	4,720.73	3.18	96.81	0.01	0.00	0.00
1030	24,518.16	11.51	88.22	0.17	0.10	0.00
1031	31,254.55	0.96	98.99	0.05	0.01	0.00
1032	19,714.67	0.76	99.19	0.05	0.01	0.00
1033	74,782.00	4.17	95.40	0.38	0.04	0.00
1034	36,055.14	0.83	98.88	0.29	0.01	0.00
1035	33,556.41	8.41	91.34	0.17	0.08	0.00
1037	207,750.14	7.06	91.41	1.37	0.10	0.07
1041	46,402.55	16.76	81.87	1.16	0.20	0.00
1042	48,383.98	16.22	82.15	1.44	0.19	0.00
1043	36,949.49	3.39	95.76	0.71	0.14	0.00
1044	37,090.00	3.72	95.39	0.71	0.17	0.00
1092	29,479.17	1.06	98.74	0.05	0.15	0.00
1093	33,526.20	1.06	98.53	0.26	0.14	0.00
1094	36,477.78	2.43	96.86	0.57	0.13	0.00
1095	4,904.78	0.00	99.59	0.19	0.22	0.00
1096	2,742.67	0.00	99.84	0.16	0.00	0.00
1097	1,426.89	0.00	100.00	0.00	0.00	0.00
1098	2,630.05	0.00	100.00	0.00	0.00	0.00
1099	8,043.33	3.29	96.55	0.00	0.15	0.00
1100	3,269.34	0.00	100.00	0.00	0.00	0.00
1101	409.59	0.00	100.00	0.00	0.00	0.00
1102	4,718.63	37.96	61.99	0.00	0.05	0.00
1104	171.09	0.00	98.50	1.50	0.00	0.00
1105	311.43	0.00	99.18	0.82	0.00	0.00
1106	2,072.65	0.30	99.30	0.27	0.12	0.00
1107	8,117.89	1.01	98.71	0.15	0.13	0.00
1108	12,270.11	2.03	97.72	0.12	0.14	0.00
1109	22,770.84	12.35	87.25	0.08	0.32	0.00

Table 101.2.1 (continued).

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1110	35,330.78	8.29	91.44	0.06	0.21	0.00
1112	1,849.03	4.19	95.81	0.00	0.00	0.00
1113	5,820.64	3.64	96.32	0.00	0.04	0.00
1114	259.36	0.00	100.00	0.00	0.00	0.00
1115	2,284.23	0.00	99.89	0.00	0.11	0.00
1116	22,270.74	3.08	96.71	0.05	0.16	0.00
1118	8,991.62	6.42	93.30	0.12	0.16	0.00
1119	56,591.82	6.34	93.31	0.19	0.16	0.00
1120	219,934.69	1.00	97.62	1.22	0.15	0.01
1121	10,364.86	0.00	99.90	0.03	0.07	0.00
1122	17,457.86	0.32	99.55	0.09	0.04	0.00
1123	6,573.50	0.00	99.79	0.21	0.00	0.00
1124	15,693.83	0.35	99.59	0.06	0.00	0.00
1125	10,295.29	0.05	99.90	0.05	0.00	0.00
1128	90,947.51	4.58	95.03	0.29	0.02	0.09
1129	83,846.46	4.89	94.78	0.21	0.02	0.10
1130	1,852.95	4.99	95.01	0.00	0.00	0.00
1131	3,170.90	37.99	61.94	0.04	0.03	0.00
1132	1,203.01	5.85	94.11	0.04	0.01	0.00
1134	16,577.17	0.18	99.75	0.06	0.00	0.00
1135	4,161.30	0.60	99.40	0.00	0.00	0.00
1136	8,939.12	0.05	99.83	0.12	0.00	0.00
1137	3,677.12	0.00	100.00	0.00	0.00	0.00
1138	5,394.46	2.70	97.28	0.00	0.02	0.00
1139	5,843.99	0.00	100.00	0.00	0.00	0.00
1141	215,105.47	6.80	91.45	1.55	0.14	0.07
1142	8,991.17	16.28	83.72	0.00	0.00	0.00
1143	5,401.11	1.68	98.32	0.00	0.00	0.00
1144	3,448.69	0.00	98.96	1.04	0.00	0.00
1145	126,238.05	1.22	97.23	1.37	0.08	0.09
1146	130,198.97	1.20	97.04	1.59	0.09	0.09
1147	4,050.04	3.34	96.62	0.04	0.00	0.00
1148	831.74	0.00	100.00	0.00	0.00	0.00
1149	149,409.45	0.96	98.07	0.78	0.18	0.01
1150	3,381.74	0.26	99.51	0.00	0.24	0.00
1151	2,793.44	0.00	99.35	0.65	0.00	0.00
1152	980.04	0.00	100.00	0.00	0.00	0.00
1154	402.92	0.00	100.00	0.00	0.00	0.00
1155	7,959.59	0.46	98.34	1.21	0.00	0.00
1156	160,395.08	1.06	97.02	1.78	0.08	0.07
1157	10,598.63	0.00	97.98	2.02	0.00	0.00
1158	140,131.89	1.21	96.98	1.64	0.08	0.08
1159	150,794.12	0.96	98.00	0.85	0.18	0.01
1160	151,915.32	0.95	97.96	0.90	0.18	0.01
1161	160,869.00	1.12	97.77	0.92	0.17	0.01
1162	14,815.75	0.54	99.38	0.08	0.00	0.00
1163	8,251.53	0.80	99.17	0.03	0.00	0.00
1164	27,749.77	0.53	99.40	0.06	0.00	0.00
1165	2,642.44	0.00	99.98	0.02	0.00	0.00
1166	28,691.28	0.65	99.29	0.06	0.01	0.00

Table 101.2.1 (continued).

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1167	29,978.86	0.62	99.31	0.07	0.01	0.00
1168	36,667.86	0.95	97.89	1.06	0.11	0.00
1169	33,990.79	1.02	97.77	1.09	0.12	0.00
1170	39,397.01	0.88	97.97	1.05	0.10	0.00
1171	40,839.67	0.85	97.99	1.06	0.10	0.00
1172	4,025.64	0.06	99.93	0.01	0.00	0.00
1173	2,872.69	1.20	98.78	0.00	0.02	0.00
1174	12,467.45	0.23	99.53	0.23	0.01	0.00
1175	25,457.44	1.34	98.39	0.15	0.12	0.00
1176	174,333.04	1.05	97.87	0.90	0.16	0.01
1177	185,086.83	1.00	97.83	1.01	0.15	0.01
1178	2,521.95	0.57	99.01	0.00	0.43	0.00
1179	24,739.71	1.33	98.53	0.08	0.06	0.00
1180	110,771.99	1.28	97.96	0.62	0.12	0.02
1181	18,452.06	0.05	98.97	0.43	0.55	0.00
1182	9,769.93	0.00	99.74	0.23	0.03	0.00
1183	9,918.28	0.02	99.76	0.21	0.01	0.00
1184	11,774.54	2.79	96.98	0.11	0.13	0.00
1185	6,451.98	20.62	79.38	0.00	0.00	0.00
1186	8,384.05	15.87	84.13	0.00	0.00	0.00
1187	4,353.22	1.26	98.74	0.00	0.00	0.00
1188	14,619.12	0.79	98.35	0.86	0.00	0.00
1189	5,093.70	4.45	94.83	0.66	0.00	0.06
1190	4,922.68	5.41	93.68	0.91	0.00	0.00
1191	3,287.08	1.86	98.04	0.00	0.10	0.00
1192	3,874.54	5.26	94.74	0.00	0.00	0.00
1193	216,641.06	6.89	91.53	1.39	0.13	0.07
1194	229,277.86	1.12	97.22	1.47	0.16	0.03
1195	235,363.56	1.34	96.79	1.58	0.19	0.09
1196	32,160.65	12.13	87.56	0.05	0.01	0.26
1197	5,655.50	0.01	99.99	0.00	0.00	0.00
1198	7,475.48	1.12	98.46	0.26	0.17	0.00
1199	4,758.29	1.65	96.91	1.43	0.00	0.00
1200	14,643.72	0.57	99.20	0.15	0.08	0.00
1201	53,668.82	7.34	92.42	0.09	0.00	0.15
1202	45,524.63	16.72	82.34	0.77	0.17	0.00
1203	52,097.54	15.15	82.88	1.79	0.18	0.00
1205	150,725.04	8.35	90.55	0.94	0.09	0.08
1206	155,114.32	8.13	90.71	0.98	0.10	0.08
1207	190,931.41	7.53	91.20	1.12	0.08	0.07
1208	196,091.34	7.34	91.20	1.30	0.09	0.07
1301	16,282.66	12.59	86.83	0.07	0.00	0.51
1302	23,502.25	16.59	83.00	0.05	0.01	0.35
1305	35,867.84	1.79	97.53	0.55	0.14	0.00
1306	132,677.63	1.18	97.01	1.64	0.09	0.09
1307	155,797.73	1.09	97.05	1.71	0.08	0.07
1500	241,701.08	1.32	96.68	1.71	0.19	0.10
1501	4,215.13	0.00	99.51	0.49	0.00	0.00
1502	10,560.69	0.27	99.52	0.20	0.01	0.00
1503	16,103.02	2.04	97.79	0.08	0.09	0.00

Table 101.2.1 (continued).

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1504	20,937.97	1.57	98.28	0.08	0.07	0.00
1505	11,050.40	2.25	97.47	0.12	0.15	0.00
1506	9,614.10	0.05	99.84	0.11	0.00	0.00
1507	11,769.65	0.00	99.83	0.17	0.00	0.00
1508	25,465.27	0.64	98.90	0.42	0.05	0.00
1509	56,843.87	6.93	92.84	0.08	0.00	0.15

Watershed boundaries were determined by joining modern 7.5-min. topographic maps and following the contour lines to determine the drainage basins for each station. Station watersheds extending outside the boundaries of Champaign County were also included in all analyses (Figure 101.2.1). The Salt Fork and Middle Fork watersheds were digitized previously (Osborne & Wiley 1988) using similar methods. Land-use/cover patterns were interpreted from the same maps for the 1980's and from 15-min. (1:64,000) USGS topographic maps produced between 1950 and 1958 (except the Monticello quadrangle produced in 1948) were used for the historical analysis. All land-use/cover patterns were drawn on computer generated plots of each specific map quadrangle and digitized on a Prime 9955-II computer. ARC/INFO (Environmental Systems Research Institute), a vector-based geographic information system, was used in data analysis.

For both modern and historical coverages land use/cover patterns were categorized according to the LUDA system (Anderson et al. 1976). Five land-use categories were employed in the present study: urban and built-up land, agricultural land, forest land, water (lakes, reservoir, and streams), and barren lands (*e.g.*, mining areas). Land use/cover patterns were digitized as polygons (enclosed areas), stream networks as line coverages, and stations as point coverages. All digitized coverages were converted to a standardized geographic reference scale (Lambert feet) and merged with adjacent coverages of the same type (*i.e.*, polygon, line, or point) to form a single coverage representing watershed land-use/cover patterns, stream network, and sampling sites in Champaign County.

The total acreage of the drainage area of each station and the total area of each land use/cover category in each sampling station for each era (modern and historical) were determined using Arc/Info software. The data from the two time periods were compared to one another to provide an overall assessment of changes in each land use category over the 30-year period and for each of the six major drainage basins in Champaign County.

Buffer Analysis

Because of the importance of riparian vegetation to stream fish communities we investigated changes in land cover at varying distances from the stream over the 30-year period. Land-use/cover patterns within 100, 200, and 400 ft. of the stream channel were determined using the ARC/INFO "buffer" facility for each station watershed. Land use for each watershed was coded in the database and linked to coverages. Total acreage and percentage of each land use for each stream buffer and watershed were calculated and data from the modern era compared to those from the historical coverage to determine if changes in land use within a watershed were adjacent to stream channels.

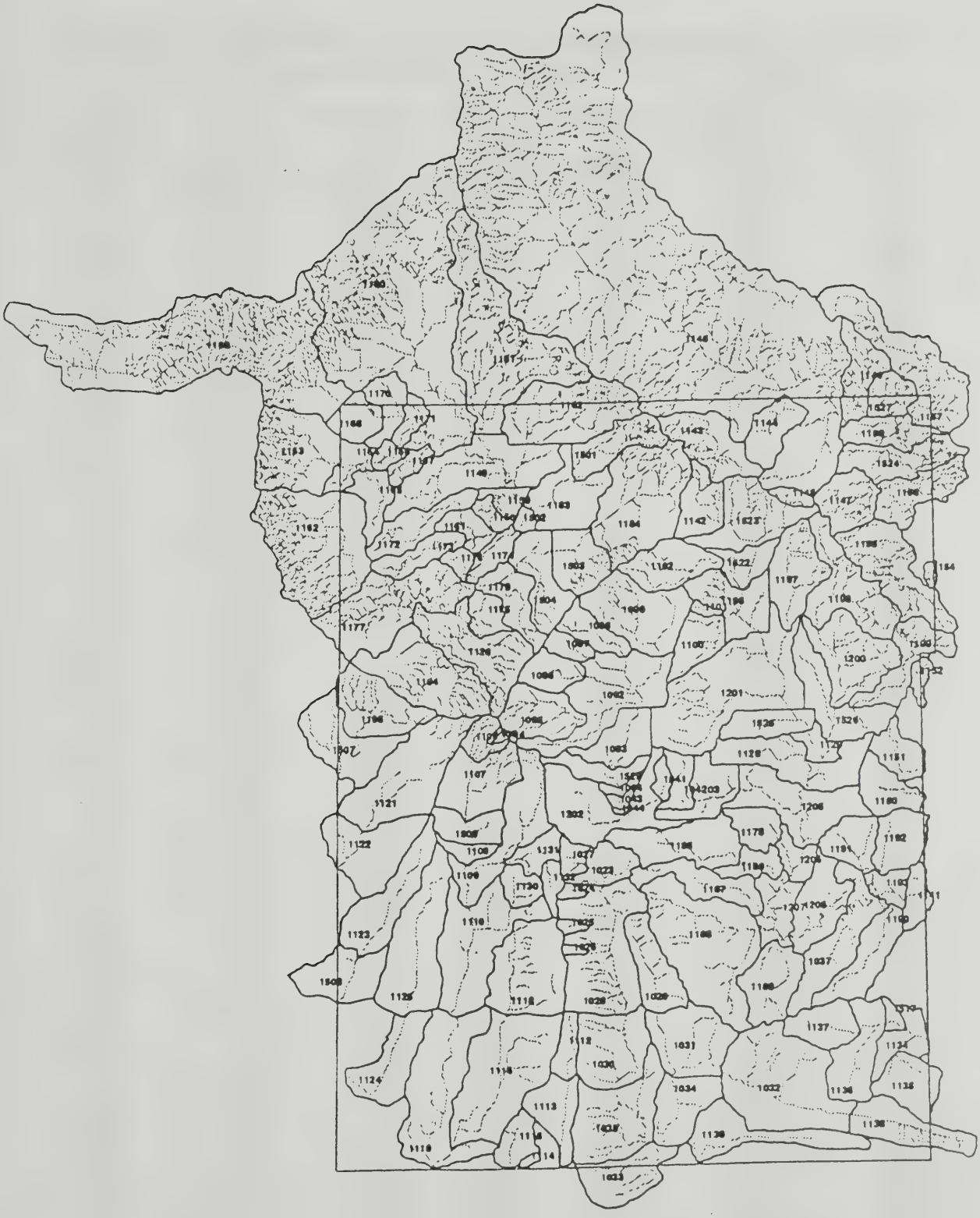


Figure 101.2.1. Watersheds of each individual sampling station. Note that upstream watersheds are also included in the drainage of downstream stations.

Table 101.2.2. The percent of each major land use category (LUDA level I) and the total acres of land in each station watershed based on historical (1959) map interpretation.

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1023	3978.13	31.87	67.87	0.26	0.00	0.00
1024	460.18	0.00	98.50	1.50	0.00	0.00
1025	491.79	2.03	96.46	1.52	0.00	0.00
1026	305.67	0.00	100.00	0.00	0.00	0.00
1027	1220.17	34.31	65.69	0.00	0.00	0.00
1028	17481.32	8.86	90.79	0.31	0.04	0.00
1029	4720.87	2.05	97.64	0.31	0.00	0.00
1030	24518.06	6.32	93.29	0.37	0.03	0.00
1031	31248.05	0.75	98.81	0.45	0.00	0.00
1032	19708.11	0.69	98.95	0.36	0.00	0.00
1033	74782.57	2.39	96.95	0.65	0.01	0.00
1034	36048.63	0.65	98.53	0.82	0.00	0.00
1035	33556.47	4.63	94.98	0.38	0.02	0.00
1037	207740.46	5.46	93.10	1.42	0.01	0.01
1041	46402.28	13.45	85.50	1.04	0.00	0.01
1042	48383.66	12.90	85.79	1.30	0.00	0.01
1043	36949.49	2.73	96.47	0.80	0.00	0.00
1044	37090.00	3.10	96.10	0.80	0.00	0.00
1092	29479.14	0.67	99.14	0.19	0.00	0.00
1093	33526.02	0.70	98.72	0.58	0.00	0.00
1094	36477.78	1.60	97.59	0.81	0.00	0.00
1095	4904.78	0.00	99.93	0.07	0.00	0.00
1096	2742.67	0.09	99.82	0.09	0.00	0.00
1097	1426.88	0.00	99.90	0.10	0.00	0.00
1098	2629.95	0.06	99.88	0.06	0.00	0.00
1099	8043.33	2.20	97.78	0.03	0.00	0.00
1100	3269.37	0.00	99.72	0.28	0.00	0.00
1101	409.59	0.00	100.00	0.00	0.00	0.00
1102	4718.69	36.43	63.52	0.05	0.00	0.00
1104	171.09	0.00	100.00	0.00	0.00	0.00
1105	311.42	0.00	98.65	1.35	0.00	0.00
1106	2072.57	1.43	97.88	0.69	0.00	0.00
1107	8117.89	0.47	99.21	0.31	0.00	0.00
1108	12270.11	1.20	98.59	0.21	0.00	0.00
1109	22770.82	3.75	96.05	0.15	0.04	0.00
1110	35330.74	2.57	97.20	0.20	0.03	0.00
1112	1849.04	3.35	96.65	0.00	0.00	0.00
1113	5820.32	2.74	97.26	0.00	0.00	0.00
1114	254.33	0.00	100.00	0.00	0.00	0.00
1115	2275.53	0.00	100.00	0.00	0.00	0.00
1116	22270.76	4.01	95.90	0.08	0.02	0.00
1118	8991.64	9.50	90.36	0.09	0.04	0.00
1119	56590.69	3.30	95.99	0.69	0.02	0.00
1120	219886.24	0.90	97.74	1.29	0.07	0.00
1121	10364.71	0.00	99.92	0.08	0.00	0.00
1122	17457.74	0.45	99.48	0.08	0.00	0.00
1123	6573.5	0.00	99.93	0.07	0.00	0.00
1124	15686.17	0.30	99.70	0.00	0.00	0.00

Table 101.2.2 (continued).

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1125	10292.19	0.06	99.94	0.00	0.00	0.00
1128	90945.58	3.78	95.81	0.39	0.01	0.01
1129	83844.21	4.10	95.60	0.28	0.02	0.01
1130	1852.95	0.00	99.86	0.14	0.00	0.00
1131	3170.88	14.86	84.83	0.30	0.00	0.00
1132	1203.16	0.10	99.67	0.22	0.01	0.00
1134	16572.65	0.30	99.35	0.36	0.00	0.00
1135	4162.59	1.00	99.00	0.00	0.00	0.00
1136	8938.56	0.09	99.32	0.60	0.00	0.00
1137	3677.01	0.00	99.21	0.79	0.00	0.00
1138	5387.83	2.42	97.29	0.29	0.00	0.00
1139	5842.97	0.02	99.90	0.07	0.00	0.00
1141	215099.15	5.27	93.04	1.66	0.02	0.02
1142	8991.09	11.11	88.64	0.19	0.00	0.06
1143	5401.00	2.76	96.95	0.29	0.00	0.00
1144	3448.69	0.00	99.71	0.29	0.00	0.00
1145	126141.31	1.00	97.78	1.00	0.21	0.01
1146	130102.32	0.97	97.58	1.22	0.21	0.03
1147	4049.96	2.59	97.35	0.03	0.03	0.00
1148	831.79	0.00	99.72	0.28	0.00	0.00
1149	149360.98	0.94	98.07	0.91	0.08	0.00
1150	3382.13	0.11	99.69	0.19	0.00	0.00
1151	2794.52	0.10	98.04	1.85	0.00	0.00
1152	978.39	0.00	99.82	0.18	0.00	0.00
1154	394.52	0.00	100.00	0.00	0.00	0.00
1155	7960.11	0.39	99.42	0.19	0.00	0.00
1156	160268.64	0.86	97.17	1.75	0.18	0.05
1157	10570.10	0.01	99.08	0.91	0.00	0.00
1158	140035.18	0.98	97.16	1.62	0.20	0.04
1159	150745.66	0.93	98.00	0.99	0.08	0.00
1160	151866.86	0.92	97.96	1.03	0.08	0.00
1161	160820.54	1.05	97.83	1.05	0.08	0.00
1162	14815.59	0.66	99.23	0.11	0.00	0.00
1163	8251.65	1.15	98.76	0.09	0.00	0.00
1164	27749.51	0.70	99.19	0.12	0.00	0.00
1165	2642.43	0.00	100.00	0.00	0.00	0.00
1166	28691.25	0.85	99.03	0.12	0.00	0.00
1167	29978.83	0.82	99.07	0.11	0.00	0.00
1168	36631.53	1.20	97.76	0.99	0.04	0.01
1169	33954.47	1.29	97.72	0.93	0.05	0.01
1170	39360.66	1.12	97.78	1.05	0.04	0.01
1171	40803.24	1.08	97.70	1.17	0.04	0.01
1172	4025.64	0.03	99.82	0.15	0.00	0.00
1173	2872.53	0.27	99.41	0.31	0.00	0.00
1174	12467.46	0.38	99.50	0.13	0.00	0.00
1175	25457.37	1.10	98.67	0.22	0.00	0.00
1176	174284.59	0.99	97.91	1.02	0.08	0.00
1177	185038.17	0.94	97.88	1.11	0.08	0.00
1178	2521.95	1.17	98.76	0.07	0.00	0.00
1179	24739.8	0.98	98.88	0.14	0.00	0.00

Table 101.2.2 (continued).

Station	Total Area (acres)	% Urban	% Ag	% Forest	% Water	% Barren Land
1180	110723.4	1.26	97.93	0.74	0.06	0.00
1181	18452.17	0.00	99.68	0.15	0.17	0.00
1182	9769.93	0.00	99.72	0.28	0.00	0.00
1183	9918.4	0.17	99.74	0.09	0.00	0.00
1184	11774.54	2.05	97.72	0.23	0.00	0.00
1185	6451.91	13.22	86.46	0.32	0.00	0.00
1186	8383.98	10.17	89.54	0.29	0.00	0.00
1187	4353.2	0.26	99.35	0.40	0.00	0.00
1188	14619.14	0.70	98.67	0.61	0.01	0.00
1189	5093.56	3.41	96.13	0.46	0.00	0.00
1190	4914.93	1.09	98.65	0.26	0.00	0.00
1191	3287.14	0.16	99.05	0.80	0.00	0.00
1192	3876.12	3.38	96.37	0.20	0.05	0.00
1193	216632.98	5.30	93.23	1.45	0.01	0.00
1194	229229.34	1.05	97.32	1.53	0.08	0.02
1195	235315.17	1.14	96.98	1.73	0.10	0.06
1196	32160.62	10.11	89.64	0.21	0.03	0.02
1197	5655.5	0.18	99.77	0.06	0.00	0.00
1198	7475.5	0.67	99.15	0.11	0.07	0.00
1199	4756.46	1.30	98.25	0.45	0.00	0.00
1200	14643.74	0.36	99.51	0.09	0.03	0.00
1201	53668.79	6.18	93.62	0.18	0.02	0.01
1202	45524.32	13.66	85.53	0.82	0.00	0.00
1203	52097.6	12.17	86.24	1.58	0.00	0.01
1205	150723.03	6.71	92.24	1.03	0.01	0.01
1206	155112.31	6.54	92.35	1.09	0.01	0.01
1207	190929.35	5.92	92.87	1.20	0.01	0.01
1208	196089.29	5.76	92.85	1.37	0.01	0.01
1301	16282.58	8.94	90.67	0.30	0.05	0.03
1302	23502.23	13.82	85.89	0.23	0.04	0.02
1305	35867.8	1.16	98.09	0.75	0.00	0.00
1306	132580.87	0.95	97.39	1.40	0.21	0.04
1307	155669.23	0.88	97.23	1.66	0.19	0.04
1500	241652.85	1.11	96.83	1.91	0.10	0.05
1501	4215.14	0.00	99.86	0.14	0.00	0.00
1502	10560.7	0.44	99.47	0.08	0.00	0.00
1503	16103.02	1.50	98.33	0.17	0.00	0.00
1504	20937.96	1.15	98.71	0.14	0.00	0.00
1505	11050.4	1.33	98.44	0.23	0.00	0.00
1506	9613.48	0.08	99.31	0.61	0.00	0.00
1507	11772.4	0.00	99.96	0.04	0.00	0.00
1508	25463.29	0.45	99.26	0.27	0.02	0.00
1509	56843.84	5.84	93.96	0.18	0.01	0.01

RESULTS

The total area of land encompassed by the watersheds of the Champaign County sampling stations was 856,263.8 acres (Figure 101.2.1). This value includes areas within the county and the watersheds of streams that flow into the county. In the late 1950's (Figure 101.2.2), 19,698.5 acres (2.3%) were urban, 824,050.9 acres (96.2%) were agriculture, 11,722.1 acres (1.37%) were forested, 573.9 acres (0.07%) were water, and 218.4 acres (0.03%) were waste or barren land (Table 101.2.2). By contrast, modern land-use patterns (Figure 101.2.3) within the same study area consist of 27,058.7 acres (3.16%) urban land, 817,174.5 acres (95.4%) agriculture, 10,715.3 acres (1.25%) forest, 1,030.0 acres (0.12%) water, and 495.5 acres (0.06%) barren land (Table 101.2.1). The minimal difference in acreages for each station drainage between Table 101.2.1 and 101.2.2 is due to the different map scales of the original data sources. These minor differences were taken into account in the final analysis and do not affect the observed patterns.

Over the past 30 years, the acreage in three land use categories have increased while two have decreased (Figure 101.2.4). The greatest absolute change was in the urban land use category which increased by 37.4% (Figure 101.2.4) or an additional 7,360 acres of land. Land in surface water increased by 79.5%, or an additional 456.1 acres. Much of this conversion appears to be associated with the creation of barrow pits during the construction of interstate highways, the development of farm ponds and Homer lake. The third category which increased in acreage during the past 30 years was barren land which increased by 126.9% or 277.1 acres (Tables 101.2.1 and 101.2.2), the single largest proportional increase in any of the land use categories. Acreage in agriculture and forested lands both decreased by 6876.4 acres (0.84%) and 1,006.8 acres (8.6%), respectively during the period (Figure 101.2.4). The low proportional decrease in agriculture land relative to the change in actual acreage reflects the dominance of agriculture land-use within the region.

Among Drainage Basins

The Sangamon River basin incorporated 259,159 acres, the most area of land in the study area, while the Little Vermilion accounted for the smallest amount of land, 16,577 acres (Figure 101.2.5). The Salt Fork basin included 225,660 acres, the Embarras basin included 88,990 acres, the Kaskaskia River basin included 97,334 acres, and the Middle Fork River basin included 168,758 acres (Figure 101.2.5).

The greatest proportional changes in land use among the six basins were in the water and wasteland categories (Figure 101.2.5). The high proportional changes in both categories was the result of the small amount of lands in these land uses in the 1950's (Table 101.2.2) which made even minor changes proportionally large. In both categories the greatest proportional change was in the Salt Fork watershed where acreage in both land use categories increased (Figure 101.2.5). The greater increase in the amount of water in the Salt Fork was largely due to the construction of Homer Lake in the eastern portion of the county. Wasteland, although minimal in absolute area (Table 101.2.1) displayed a dramatic proportional increase in the Salt Fork over the thirty year period. This increase was associated with the growth and expansion of the Champaign-Urbana sanitary landfill system. This land use also increased in the Sangamon and Middle Fork drainage basins (Figure 101.2.5).

Urbanization increased in all drainage basins except the smallest, the Little Vermilion (Figure 101.2.5). The decrease in urbanization in this basin was the result of the removal

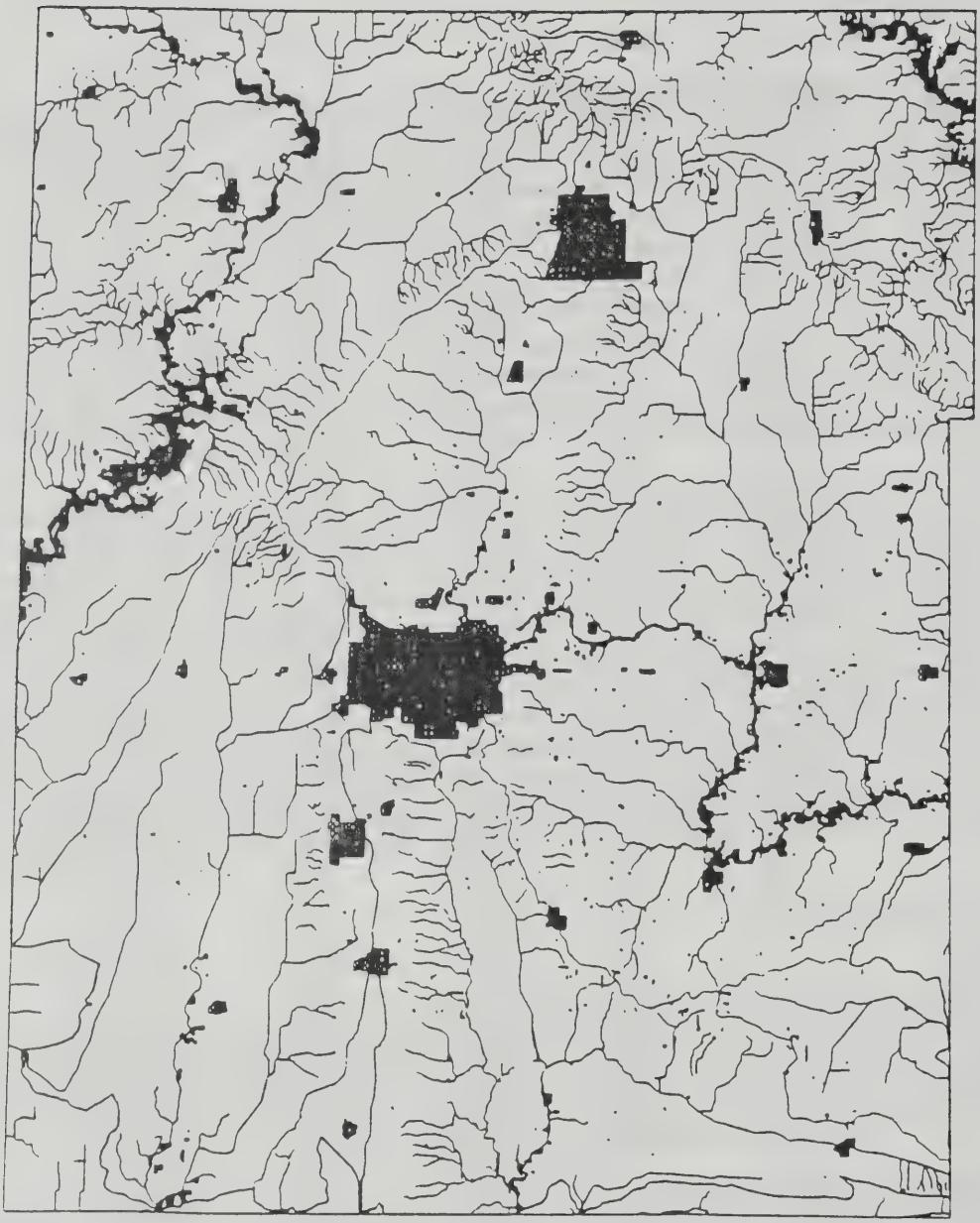


Figure 101.2.2. Landuse in Champaign County in 1958. Red indicates urban area, white indicates land in agriculture, green indicates land in forest, blue indicates water, black indicates barren land.

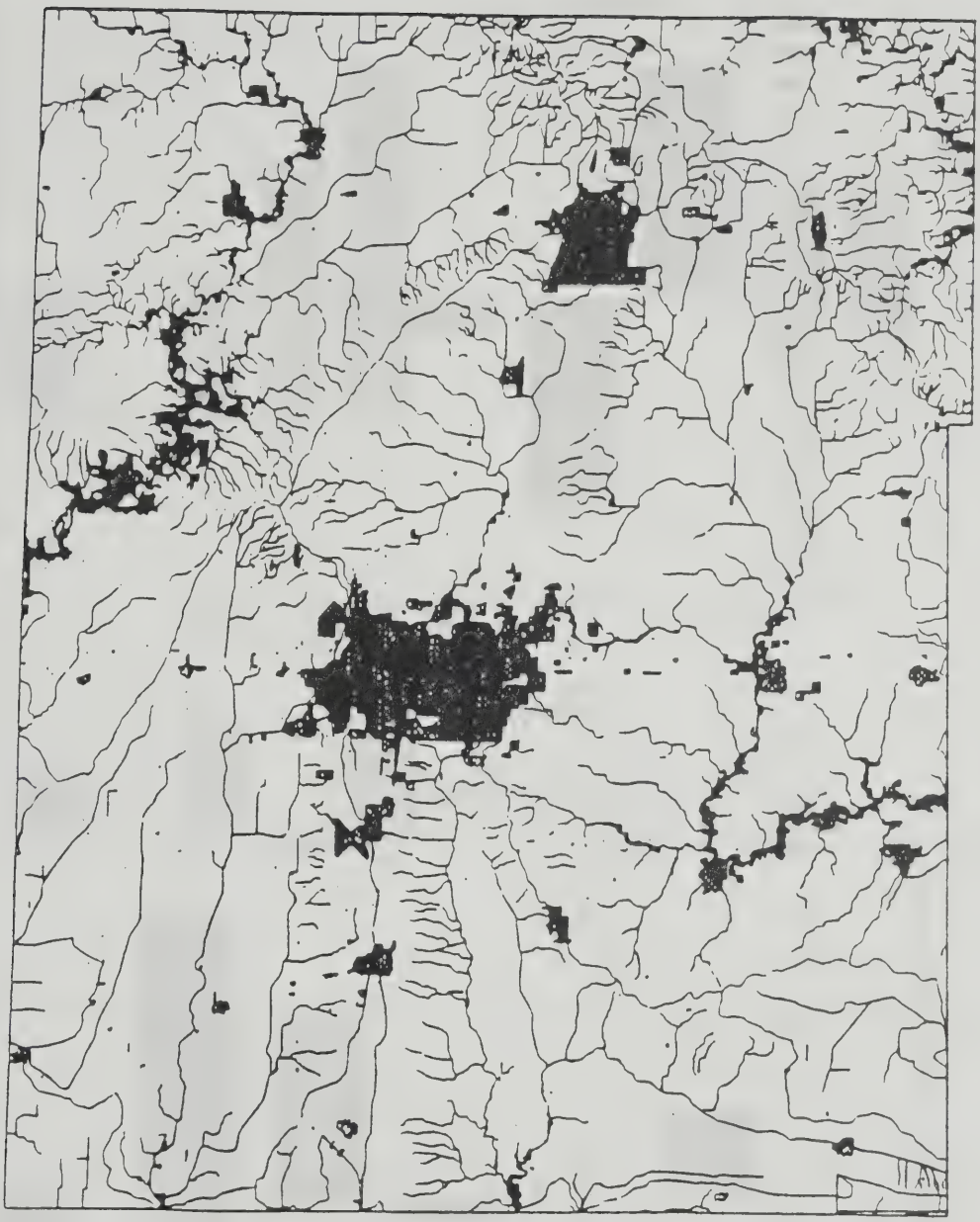


Figure 101.2.3. Modern landuse in Champaign County. Red indicates urban area, white indicates land in agriculture, green indicates land in forest, blue indicates water, black indicates barren land.

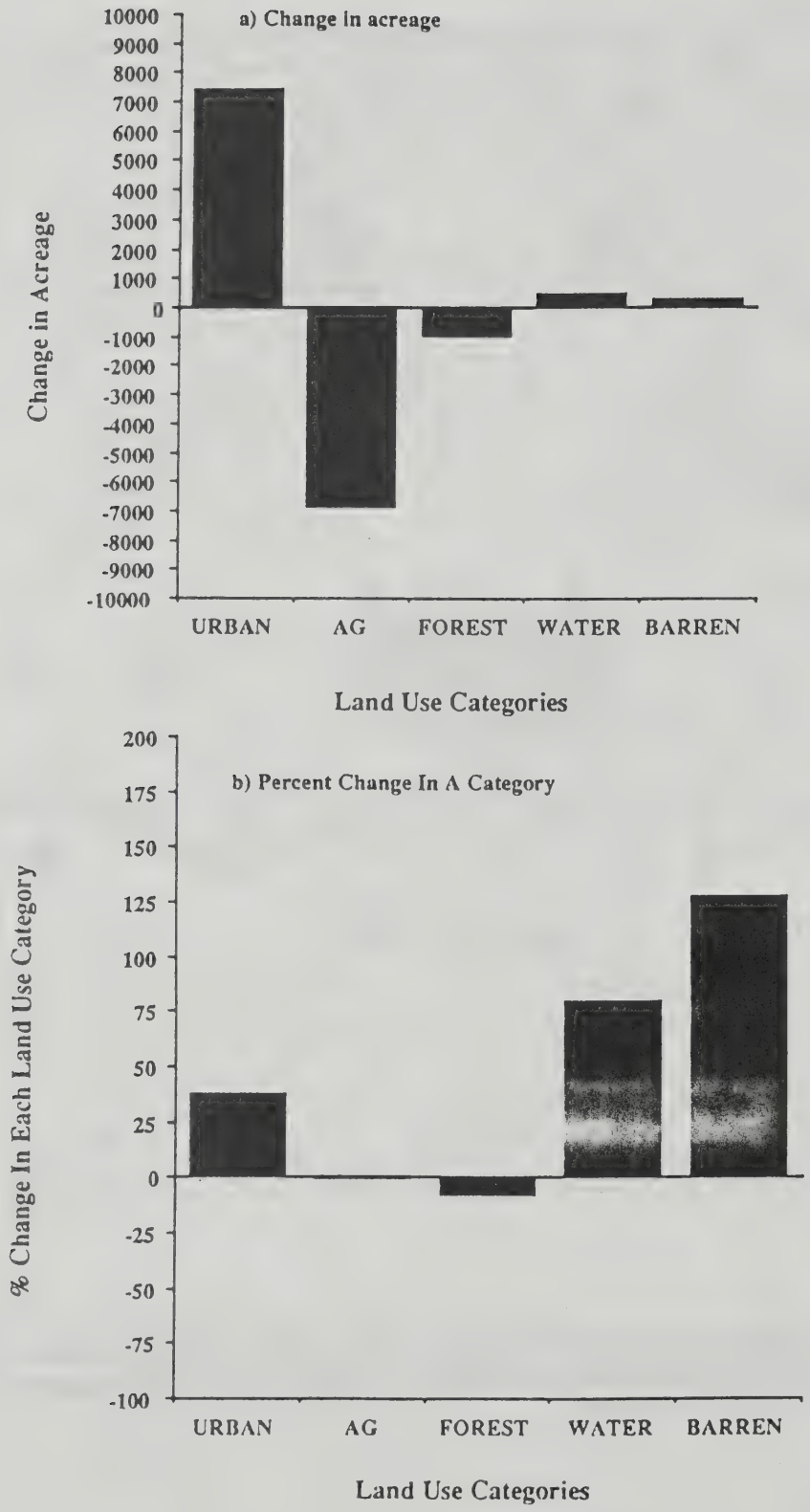


Figure 101.2.4. - Net changes in the amount of land within each land use category between the late 1950's and the 1980's. Data are presented by a) absolute acreage, and b) percent change within each category.

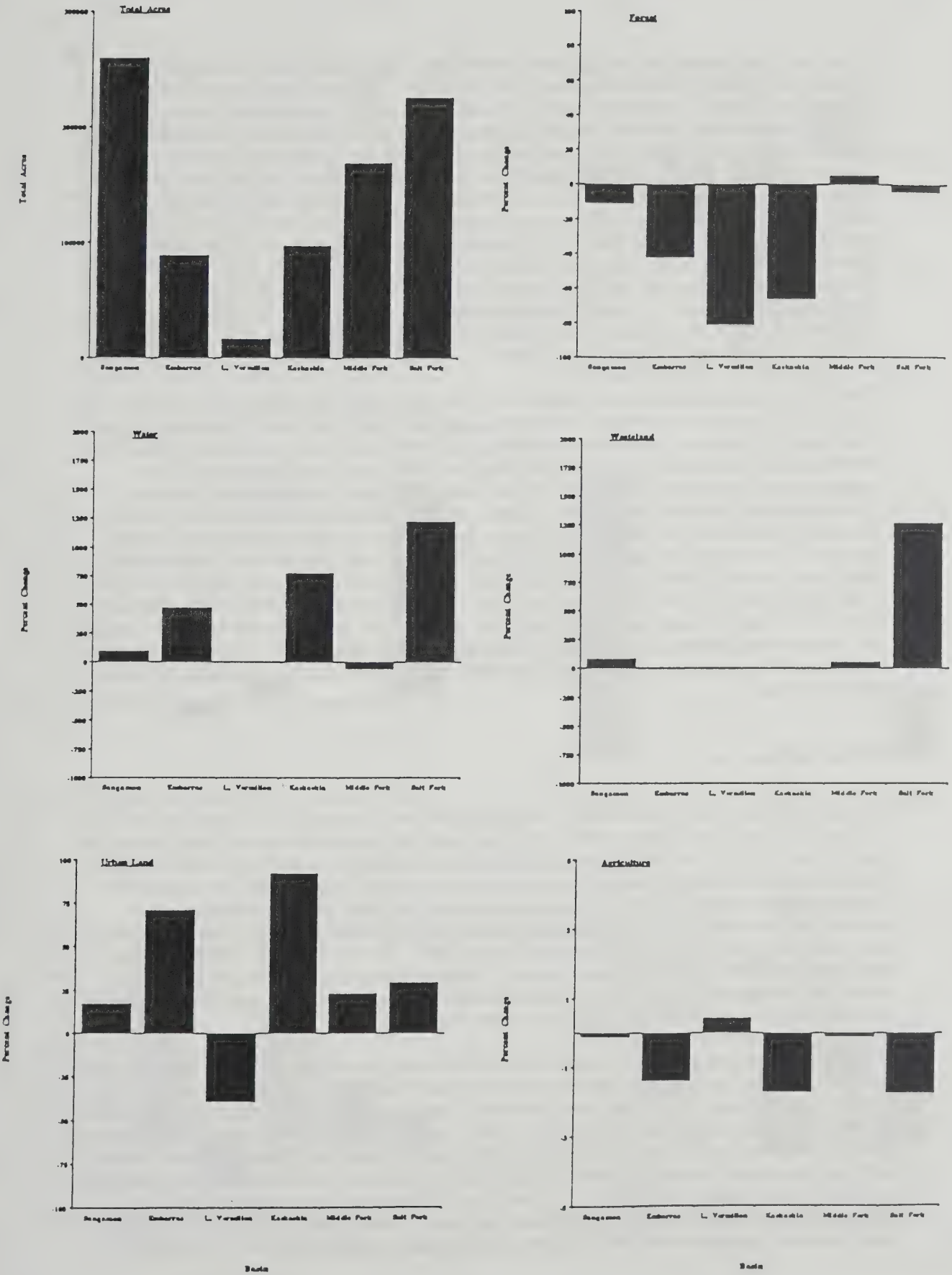


Figure 101.2.5. Net change in the proportion of land (acres) in each of the six major drainage basins in Champaign County between the 1950's and the 1980's for each landuse category.

of several older homes and an apparent conversion to agriculture land use (Figure 101.2.5). Unlike the other basins, the Little Vermilion displayed an increase in the proportion of land in agriculture use which decreased slightly in all other basins. The greatest proportional increases in urbanization were in the Embarras and Kaskaskia River basins reflecting the western and southern expansion of the Champaign-Urbana area. This increase in urban land in the Kaskaskia River and Embarras River basins corresponds to the decrease in the proportion of land in agriculture (Figure 101.2.5). Although a 1 to 2 percent reduction did occur in the amount of lands in agriculture use, this proportional loss was insignificant relative to the 40 to 80 percent loss of forested lands that occurred in the Embarras, Little Vermilion, and Kaskaskia River basins (Figure 101.2.5). Less dramatic decreases in the amount of lands in forested use were also observed in the Salt Fork and Sangamon River basins. A small increase in the proportion of land in forest was reported in the Middle Fork River basin which can be attributed to the creation of a county park in the northeastern most portion of the county.

These data indicate that the general pattern of change in land uses within the study area was for lands in the urban, water and wasteland categories to increase and for agriculture and forest land to decrease. While this was the pattern within the study area as a whole, some inter-basin differences in the amount of change in land uses was also evident. Most apparent was the substantial growth in urban land use in the Kaskaskia and Embarras watersheds which resulted in a small proportional loss of land in the agriculture category. With the exception of the Middle Fork watershed, the greatest proportional loss across basins was the amount of land in forest. Riparian vegetation, particularly forested lands, have been shown to have significant beneficial influences on midwestern stream systems (Karr and Schlosser 1978, Schlosser and Karr 1981, Osborne and Wiley 1988, Wiley et al. 1990). Thus, a critical question is whether the decrease in land in the forested category was adjacent to streams as such losses would presumably have a greater adverse influence on stream fish populations than would conversion of forested lands more distant from the stream channel.

Within Buffers

The proportions of land converted to urban land use were substantially higher in the 100', 200' and 400' buffers (Figures 101.2.6-8) than were the basin wide averages of urban land use (Figure 101.2.5) for the Embarras, Kaskaskia, Middle Fork, and Salt Fork basins. These results demonstrate that a disproportionate amount of urbanization has occurred in the immediate vicinity of stream channels in most of the study area compared to other portions of the watershed. Because urbanization has been associated with the degradation of aquatic ecosystems (e.g., Osborne and Wiley 1988, Karr and Dudley 1981, Osborne and Herricks 1989) the greater conversion of lands adjacent to stream channels to urban areas can be expected to also have a greater impact on stream fish communities than would development in areas more distant from stream channels.

Unlike the urban category, there were minimal differences in the proportional change in the agriculture category in riparian areas relative to basin wide averages (Figures 101.2.5-8). The exception to this was the obvious increase in the proportion of riparian land converted to agriculture use in the Sangamon River basin. Despite a slight overall loss for the whole Sangamon watershed (Figure 101.2.5), the proportion of land in agriculture use increased adjacent to stream channels (Figures 101.2.6-8). An increase in agriculture land adjacent to stream channels also corresponds with a net loss in forest land use suggesting that a substantial proportion of the riparian forest that was lost when the Sangamon River basin was converted to agriculture use. The removal of riparian vegetation can be expected to

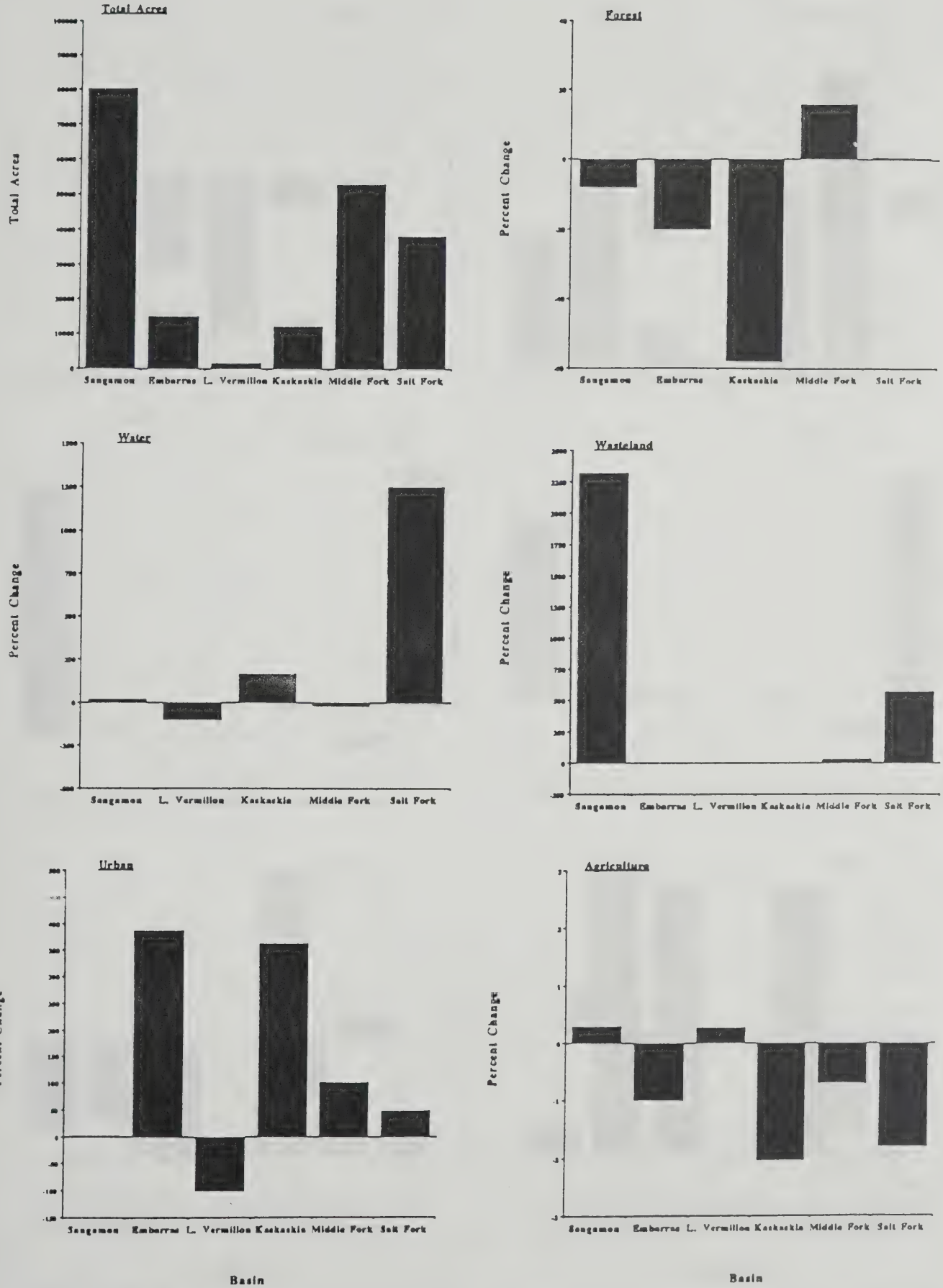


Figure 101.2.6. Net change in the proportion of land within 400' of the streams between the 1950's and the 1980's in each landuse category with respect to major drainage basins.

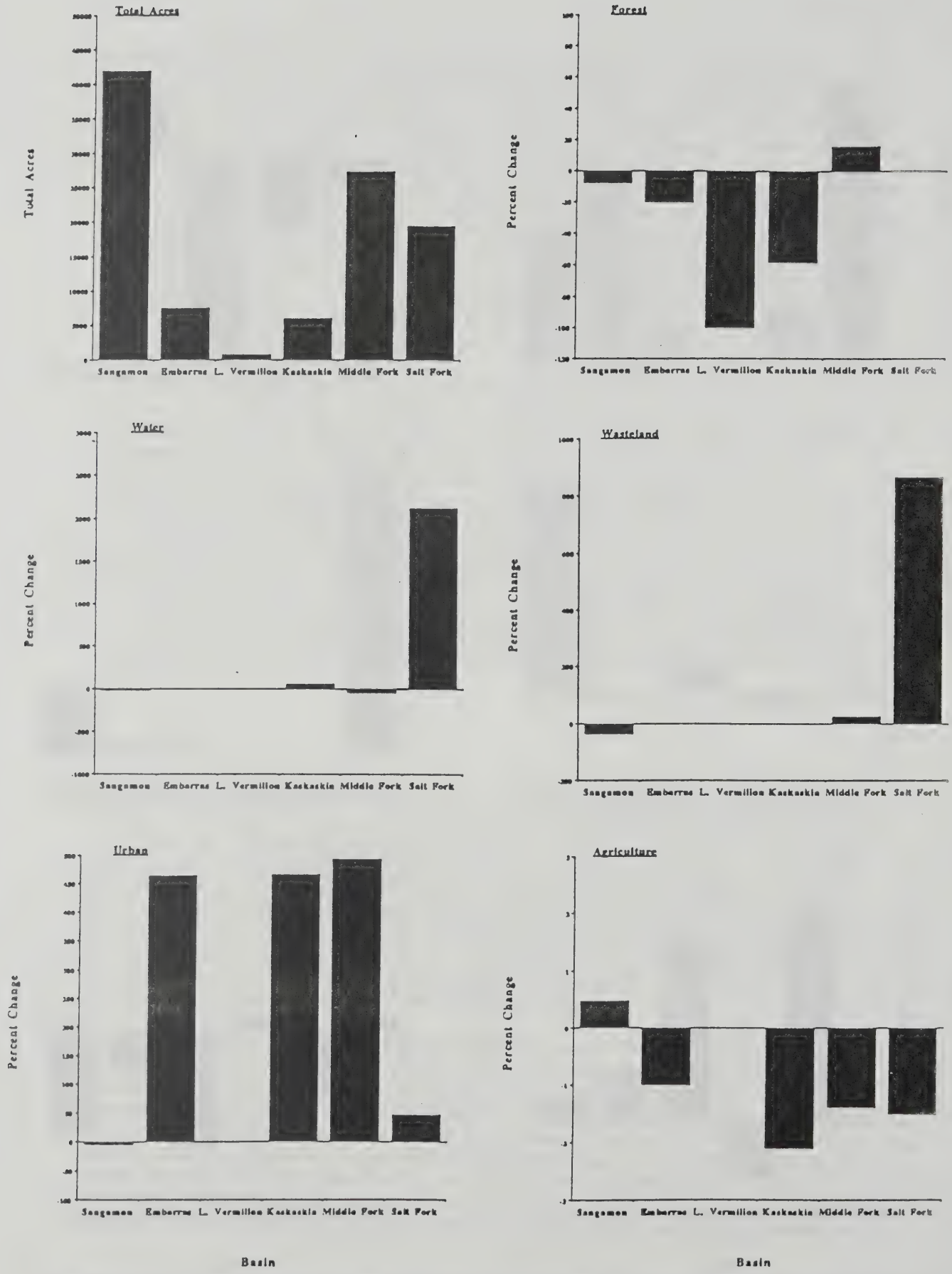


Figure 101.2.7. Net change in proportion of land within 200' of the streams between the 1950's and the 1980's in each landuse category with respect to major drainage basins.

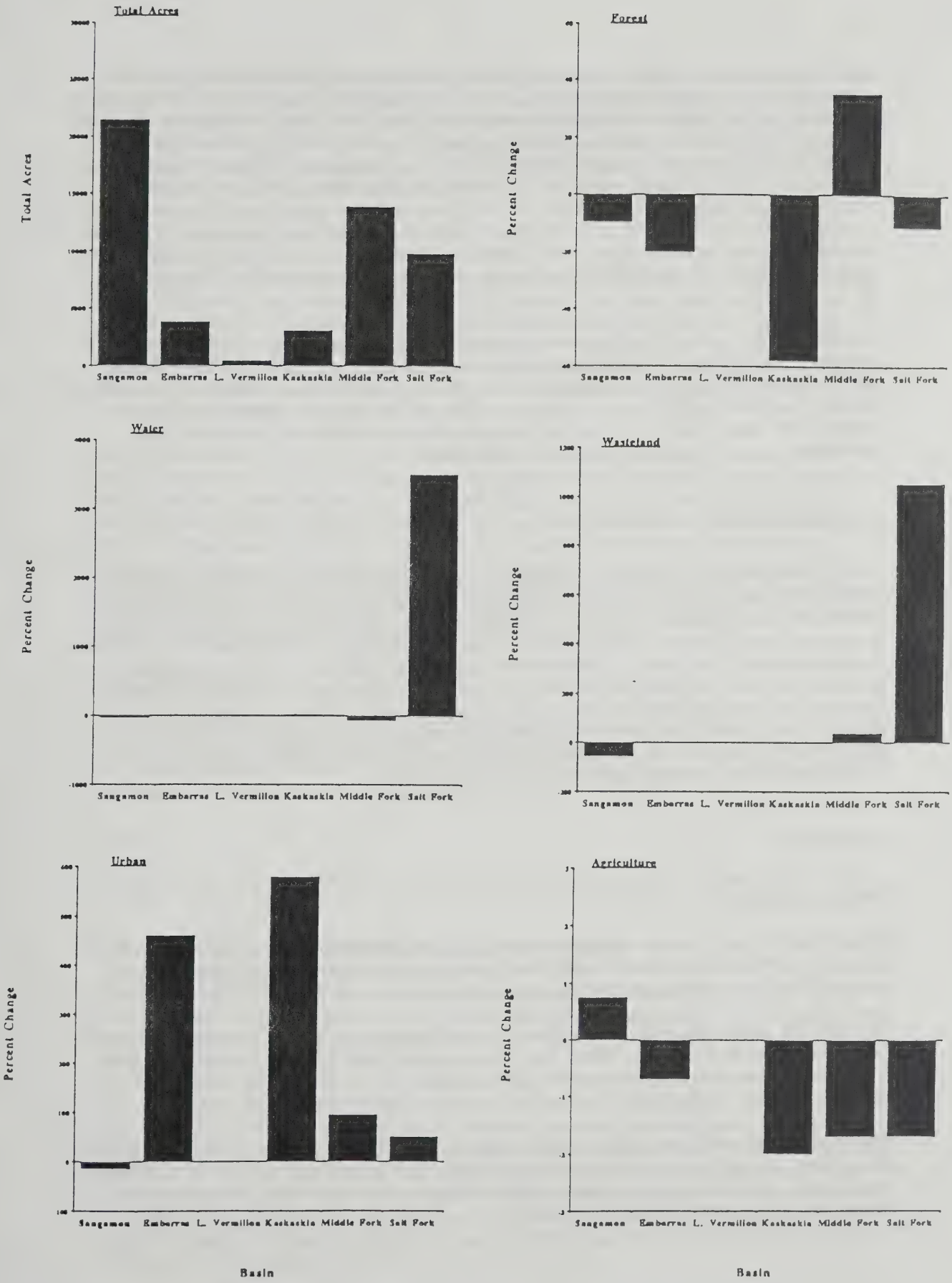


Figure 101.2.8. Net change in proportion of land within 100' of the streams between the 1950's and the 1980's in each landuse category with respect to major drainage basins.

have had substantial impacts on the integrity of the Sangamon River and its biotic communities. Loss of riparian vegetation during the past thirty years was not limited to the Sangamon River basin, nor was it only associated with conversion to agriculture land use (Figures 101.2.6-8). One hundred percent of the land within 200 feet of the stream channel and in forest use was lost (Figure 101.2. 7) and apparently converted to agriculture land use in the Little Vermilion basin. While the Little Vermilion is the smallest basin within the study area, the trend reflects an ever increasing concern of the effects on water quality (Kovacic et al. 1990) in the midwest. Similarly, a disproportionate loss of riparian forests appears to have occurred in the Kaskaskia River basin, but the loss appears to have been associated with conversion to agriculture and increased urban areas (Figures 101.2.5-8).

In summary, this investigation into the changes in land use patterns in Champaign County indicates that riparian forests and associated vegetation have suffered significant losses during the past thirty years. Depending on the drainage basin, the riparian lands have been converted to either agriculture or urban uses. The exception to this pattern was in the Middle Fork basin where more land adjacent to stream channels was converted from agriculture use to forest land use (Figures 101.2.5-8).

PHYSIO-CHEMICAL HABITAT

Merely documenting changes in composition and structure of fish communities does not indicate why such changes occurred, nor does it provide insight into factors controlling stream fish communities. Without such information, extrapolation of any results to other geographic areas, time periods, or aquatic systems is difficult, if not impossible. For these reasons detailed assessments of physio-chemical habitat conditions were made at fish sampling stations. Because of the annual variation in environmental conditions associated with the 1988 drought, analyses that relate physio-chemical habitat and riparian land use parameters to stream fish communities only included data collected in 1987. Thus, the number of habitat and water chemistry sampling stations used in these comparisons will deviate from those reported earlier (Osborne et al. 1989).

METHODS

Habitat Assessment

Stream channel and riparian conditions were measured and described at 103 fish sampling stations in 1987. Stations were located in all six major drainages in Champaign County and include all locations quantitatively sampled by Larimore & Smith (1963).

For each site and assessment date, a stream reach of approximately 100 m was divided into five equally spaced transects. When sites were accessed from a bridge crossing, the most downstream transect was approximately 30 m upstream of the bridge. Sampling commenced in an upstream direction beginning at the downstream end of a reach.

Weather and general flow conditions (high, moderate, or low) were noted during assessment. Air and water temperatures were taken with a mercury thermometer (with time noted). A qualitative assessment of fish habitat quality was made for the reach (see below) and the length of the reach measured.

Turbidity, dissolved oxygen, air and water temperature, and specific conductance were measured at sites when fish were sampled. In addition, pH, alkalinity, nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and soluble reactive phosphorus (SRP) were determined for water samples from 97 stations [including sites where Larimore & Smith (1963) took quantitative samples] in summer and fall, 1987. Field measurements and visual estimates were made at each transect at each station (Table 101.2.3).

Water Chemistry.

A Hach Model 16800 turbidimeter was used to determine turbidity of a sample that was collected prior to any instream work. A YSI Model 57 oxygen meter, which was air calibrated according to manufacturer's instructions at each site, was used to measure dissolved oxygen. Air and water temperatures were measured with a mercury thermometer. Conductivity was measured with a YSI Model 33 S-C-T meter, adjusted for the temperature (measured manually). These measurements were taken only on days when fish were collected.

For stations where more extensive water quality parameters were measured in 1987, samples were collected in Wheaton glass-stoppered bottles and transported on ice to the laboratory for immediate analysis. Total alkalinity and pH were determined with an ALTEX Model 3500 digital pH meter. Nutrients were measured with a HACH DR/3 portable water analysis instrument. The Salicylate Method was used to determine ammonia-nitrogen, the Diazotization Method (NitriVer 3 for concentrations of 0.0-0.2 mg/L) for nitrite-nitrogen, the Cadmium Reduction Method (NitraVer 6 for concentrations of 0.0-0.34 mg/L and NitraVer 5 for concentrations of 0.0-30.0 mg/L) for nitrate-nitrogen, and the Amino Acid Method for soluble reactive phosphorus.

Fish habitat rating.

The quality of a stream reach as fish habitat was rated on a scale of 0-3 (0 = poorest). '0' indicated a near absence of habitat for most species—shallow water and no pool structure. '3' indicated habitat suitable for a large diversity of game and forage fish, with a well developed pool-riffle structure and pools >3 ft deep.

Width.

Width was measured in feet between existing water edges at each transect (Platts et al. 1983).

Shore water depth, bank undercut, and vegetative overhang.

These distances were measured in centimeters, according to Platts et al. (1983) at each transect. Overhanging vegetation was defined as any plant material $\leq$1 m above the water surface (higher material was considered part of the canopy).

Discharge.

Station discharge was determined as the mean of five cross-sectional measurements of depth x velocity x transect width at each transect (5 transects/station). Measurements were taken at each bank, 1/4 width, midstream, and 3/4 width. Velocity was measured with a Marsh-McBirney 201D water current meter, calibrated at each site prior to measurements. At depths $\leq$0.65 m, velocity was taken at 0.6 depth; at depths >0.65 m, the average of velocities taken at 0.2 and 0.8 depth was used. Depth was measured with a standard staff wading rod to the nearest 0.1 ft.

Table 101.2.3. Parameters measured at each transect at each station. (e.g. The mixture of units reflect the mixture of surveying and laboratory instruments used. They do not affect the multivariate analyses which standardize all units.)

Parameters	Units
Directly Measured	
Total width	ft
Shore water depth	cm
Bank undercut	cm
Vegetative overhang	cm
Discharge	ft^3/s
Cross-sectional profile	ft
Visually Estimated	
Transect classification	riffle, run, glide, pool
Bank vegetative stability	1-4 rating
Streamside cover	1-4 rating
Channel vegetative cover	%
Canopy	%
Total shading	%
Substrate type	see text
Substrate compaction	1-5 rating
Reach description	see text

Transect classification.

Each transect was categorized as run, riffle, glide, or pool. Categorization of an area generally followed descriptions in Platts et al. (1983). The glide category was reserved for shallow, channelized drainage ditches.

Bank vegetative stability and streamside cover.

These descriptive ratings, ranging from 1-4, were applied following the system of Platts et al. (1983) (Tables 101.2.4 and 101.2.5). The streambank was considered that portion of the channel which restricts lateral water flow, with the area above included in descriptions of surrounding land use (see Reach description below).

Channel vegetative cover.

The percentage of the stream channel at each transect covered by living or dead vegetation was estimated visually. Water-surface cover and substrate cover were included.

Table 101.2.4. Descriptions for rating streambank vegetative stability (from Platts et al. 1983).

Rating	Description
4 (excellent)	>80% of the streambank surfaces are covered by vegetation in vigorous condition or by boulders and rubble. If the streambank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3 (good)	50-79 % of the streambank surfaces are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2 (fair)	25-49 % of the streambank surfaces are covered by vegetation or larger material. Those areas not covered by vegetation are covered by materials that give limited protection.
1 (poor)	<25% of the streambank surfaces are covered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

Canopy.

A visual estimate was made at each transect of the percentage of the water surface covered by vegetation ≥1 m. Canopy density was not considered in this estimate.

Total shading.

A visual estimate was made of the percentage by which total available light was reduced along the channel transect. This estimate considered shading due to canopy, channel vegetative cover, and bank height and slope, given the angle of the sun's path for the particular transect's compass angle and for the time of year.

Substrate type

At each point along the transect where depth and velocity were measured, the predominant substrate texture was determined visually and by touch. Substrate was classified as one or a combination of the following: clay; silt; sand; gravel; cobble; boulder; or plant material. The classification system of Lane (1947) [in Platts et al. (1983), p. 15], was used as a guide. Texture was estimated at the precise location of the staff used to determine depth and velocity.

Substrate compaction (penetrability)

Substrate compaction was rated at each measurement point along the transect. The rating was based on the degree to which one's foot, with little effort, penetrated the substrate (Table 101.2.6).

Reach description.

Bank height and slope at each transect were estimated visually. Surrounding land uses, beginning at the top of the banks, were noted with estimates (in ft) of the average distance each use covered. Also noted were any unusual features at the transect (e.g., drainage tiles, bank debris, or unusual material in the channel).

Table 101.2.5. Descriptions for streamside cover ratings (from Platts et al. 1983).

Rating	Description
4	The dominant vegetation is shrub.
3	The dominant vegetation influencing the streamside and/or water environment is of tree form.
2	The dominant vegetation is grass or forbs.
1	>50% of the streambank transect line intercept has no vegetation and the dominant material is soil, rock, bridge materials, road materials, culverts, or mine tailings/

Table 101.2.6. Rating descriptions for stream substrate compaction.

Rating	Description
5	Solid; no penetration or movement of substrate material
4	Solid surface, but slightly movable within surrounding material
3	Foot sinks <2 in.
2	Foot sinks ≥ 2 but < 4 in.
1	Foot sinks ≥ 4 in. (ankle-depth)

RESULTS

Box plots were constructed for each physical and chemical habitat parameter from data collected at stations sampled in 1987 (Figures 101.2.9 - 101.2.17). Box plots are presented for the average values of each parameter occurring at stations within each of the six major drainage basins in Champaign County except for total residual chlorine (TRC) which was recorded in only three of the six drainage basins (Figure 101.2.17). The minimum and maximum recorded values within a basin are reflected in the bottom and top lines respectively of each box plot except for outliers that are indicated with asterisks. The line bisecting the box itself designates the median value. The upper and lower edges of the 'box' represent the median values of the upper and lower halves of the data, respectively.

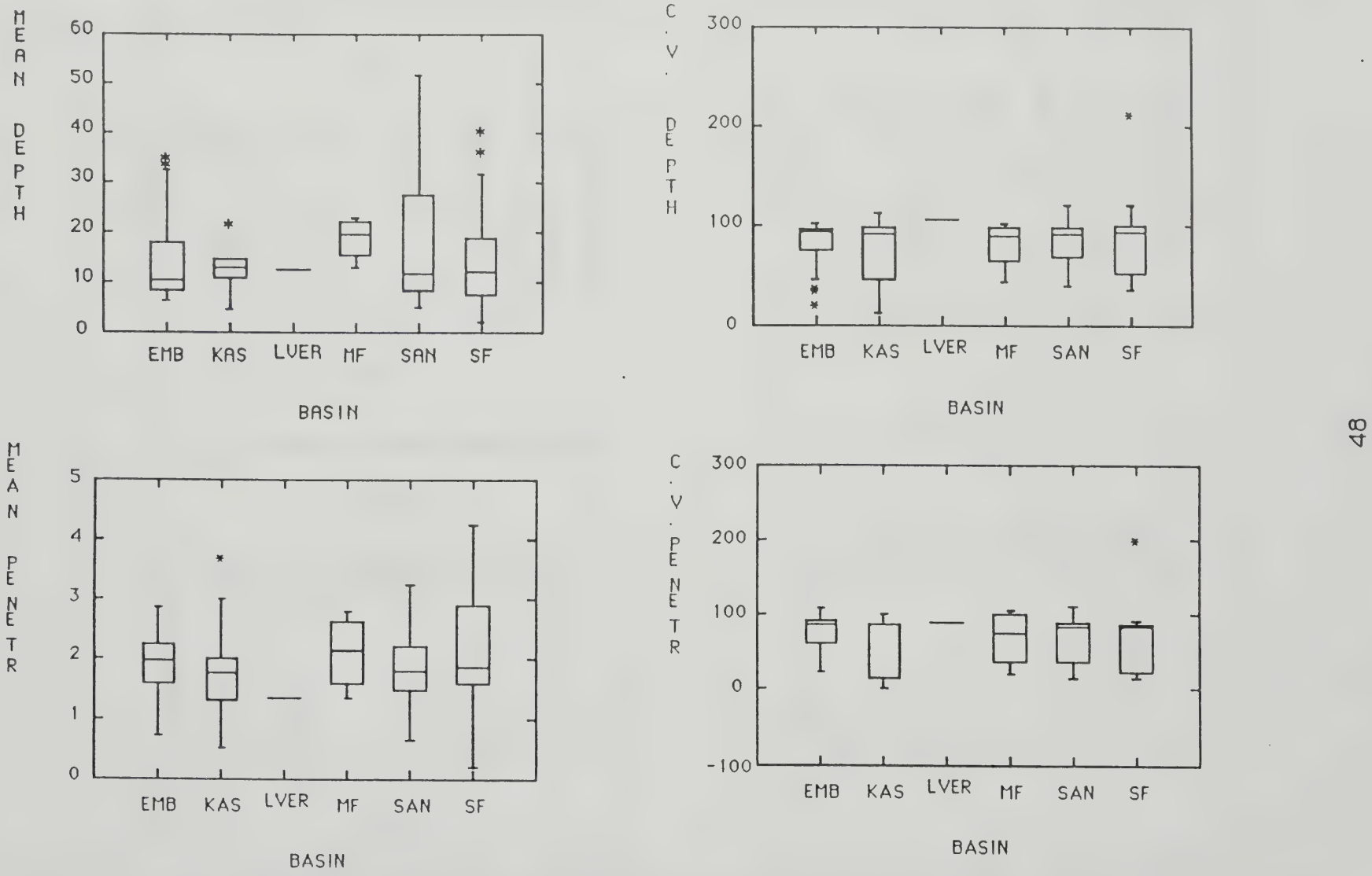


Figure 101.2.9. Box plots of mean depth, coefficient of variation in depth, mean penetrability, and coefficient of variation in penetrability for 1987 sampling stations with respect to major drainage basins in Champaign County.

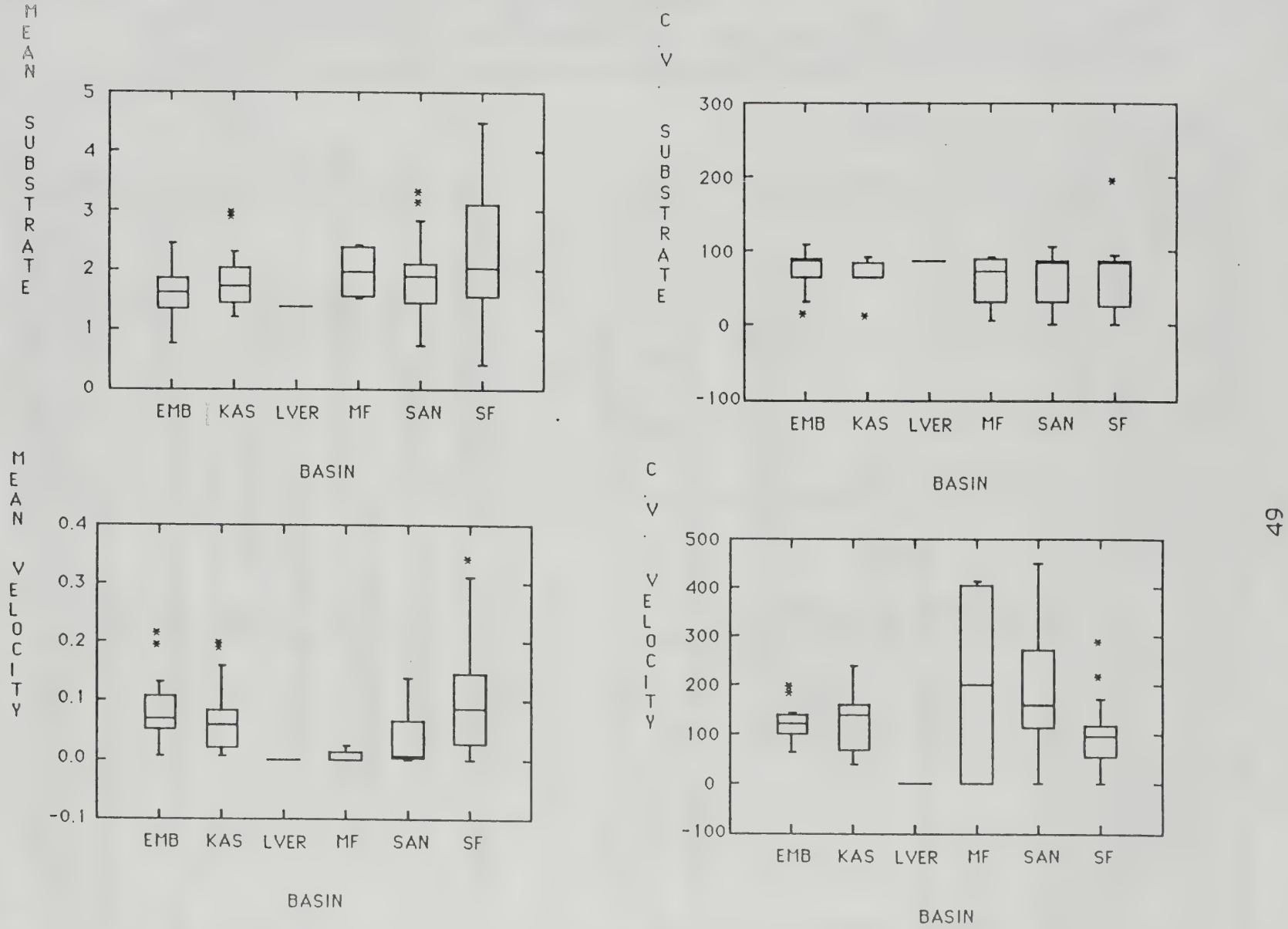


Figure 101.2.10. Box plots of mean substrate particles size, coeficient of variation in substrate particle size, mean velocity, and coeficient of variation in velocity for 1987 sampling stations with respect to major drainage basins in Champaign County.

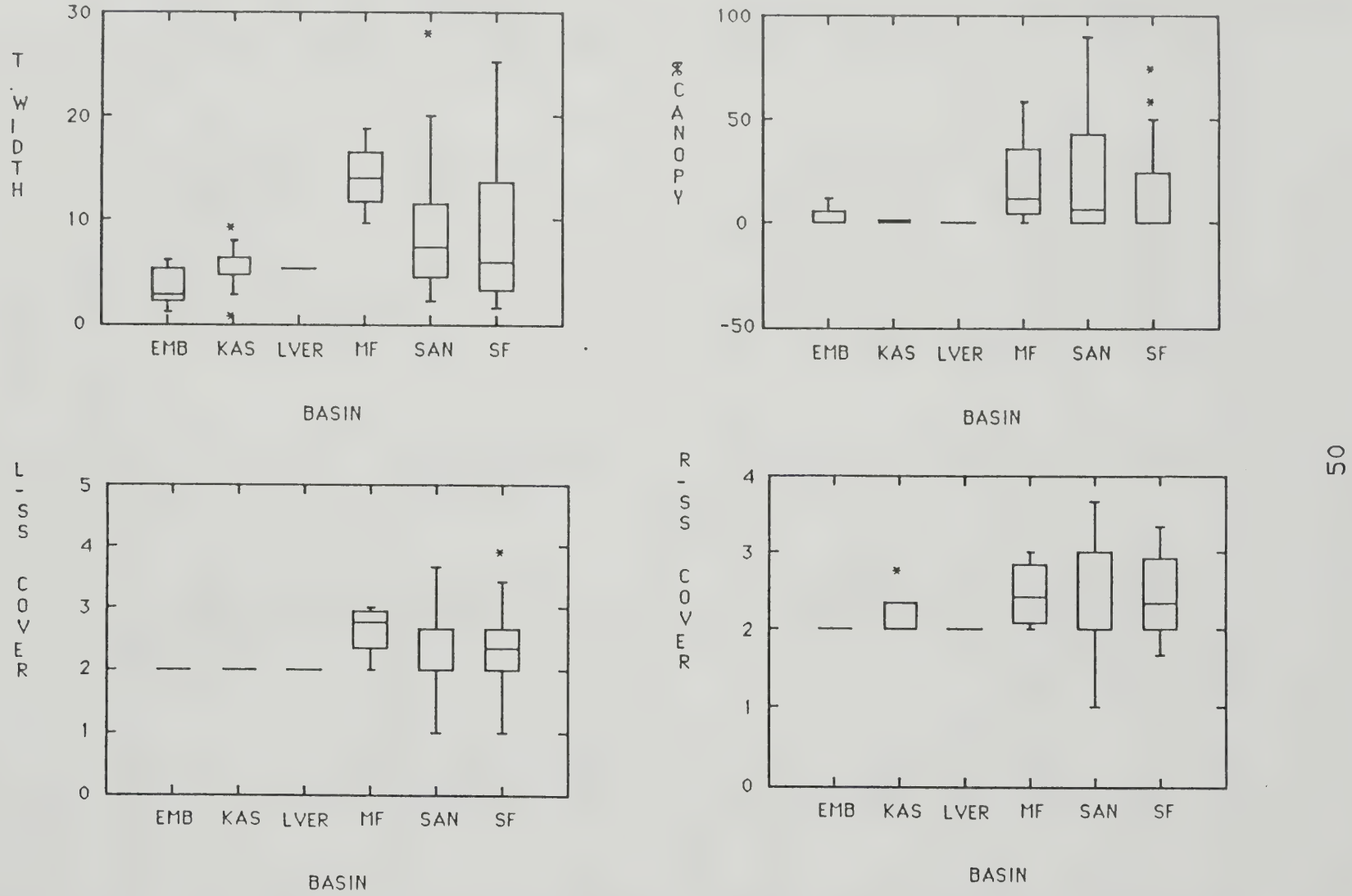


Figure 101.2.11. Box plots of the mean total width, mean percent canopy cover, and the mean right and left bank cover ratings for 1987 sampling stations in the major drainage basins of Champaign County.

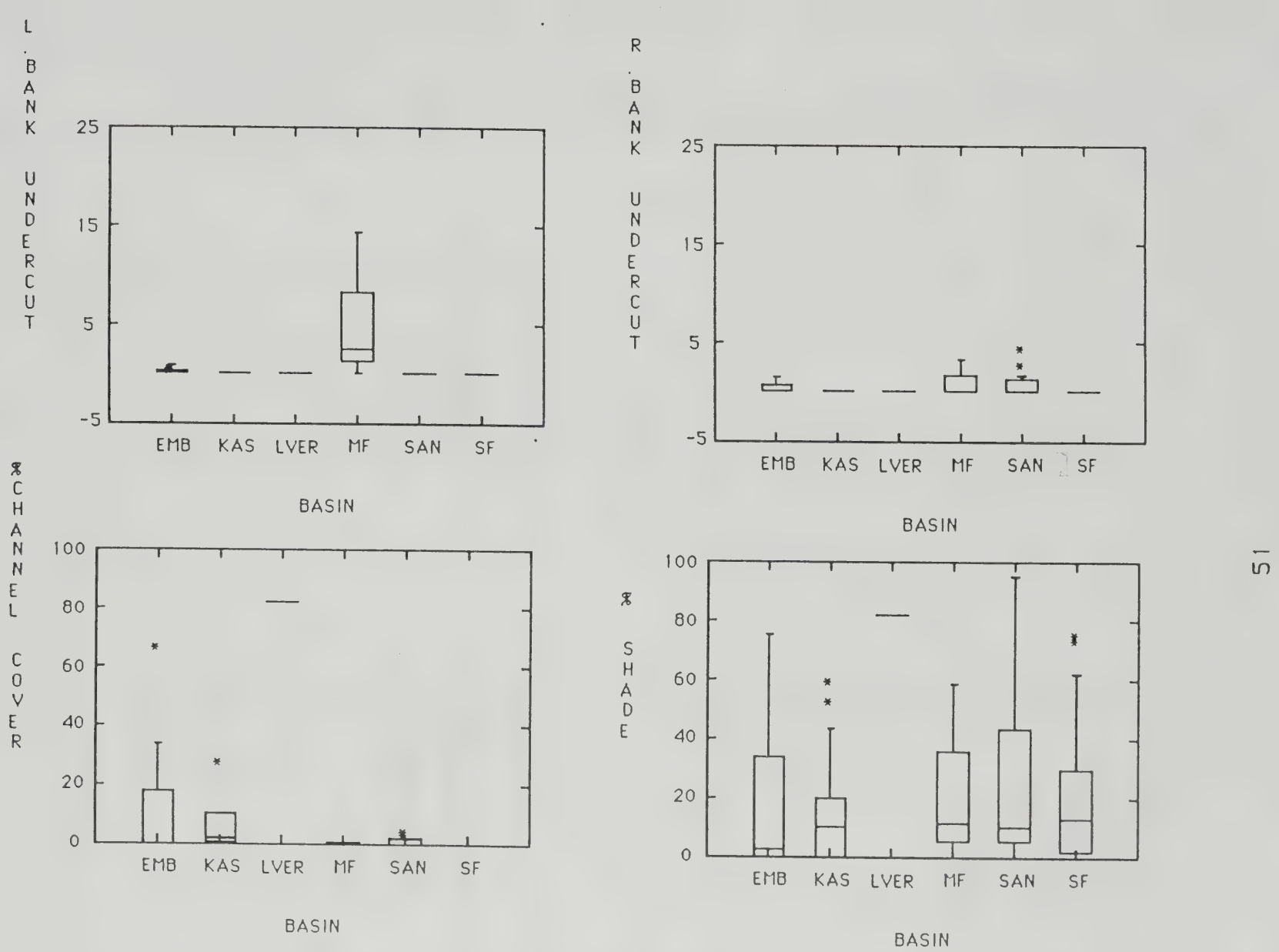


Figure 101.2.12. Box plot of average left and right bank undercut (cm), the percent vegetative cover of the channel, and the average total percent shading for 1987 sampling stations in the six major drainage basins of Champaign County.

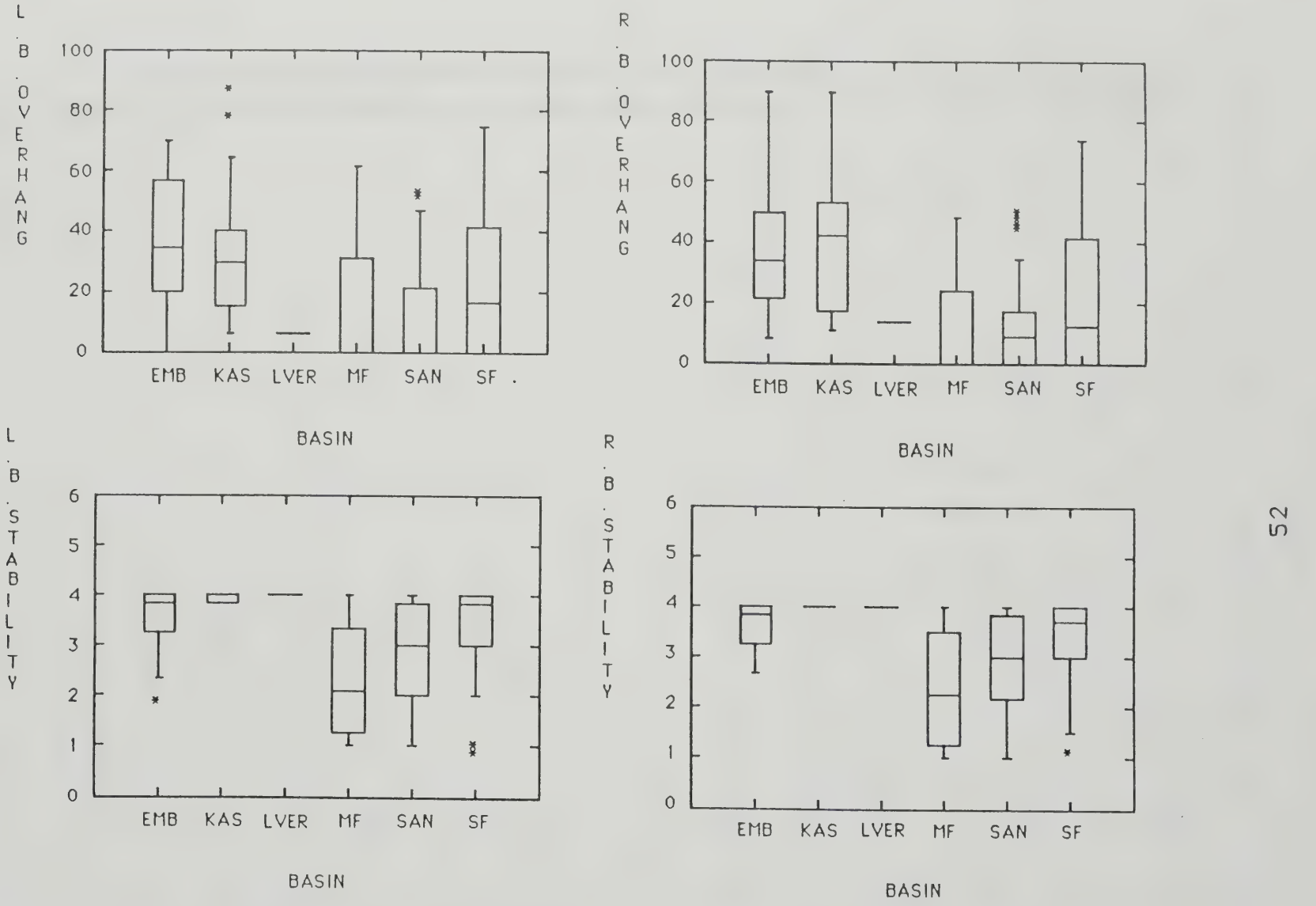
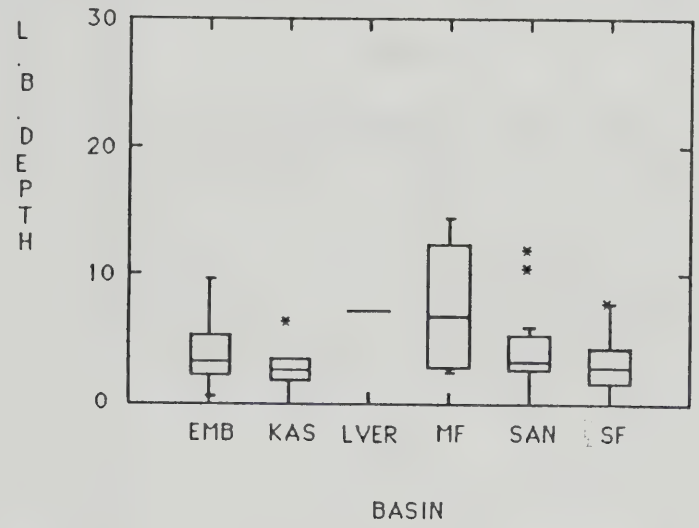


Figure 101.2.13. Box plots of mean left and right bank stability ratings and mean left and right bank vegetative overhang (cm) for 1987 sampling stations in the six major drainage basins of Champaign County.



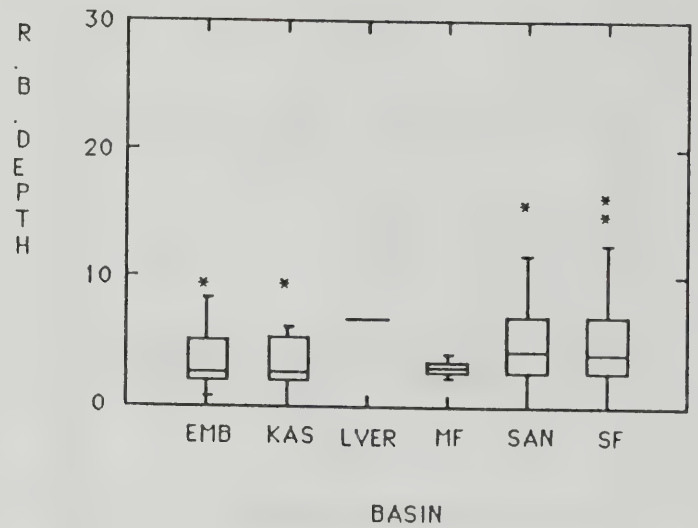


Figure 101.2.14. Box plots of mean left and right bank water depths at 1987 sampling stations in the six major drainage basins of Champaign County.

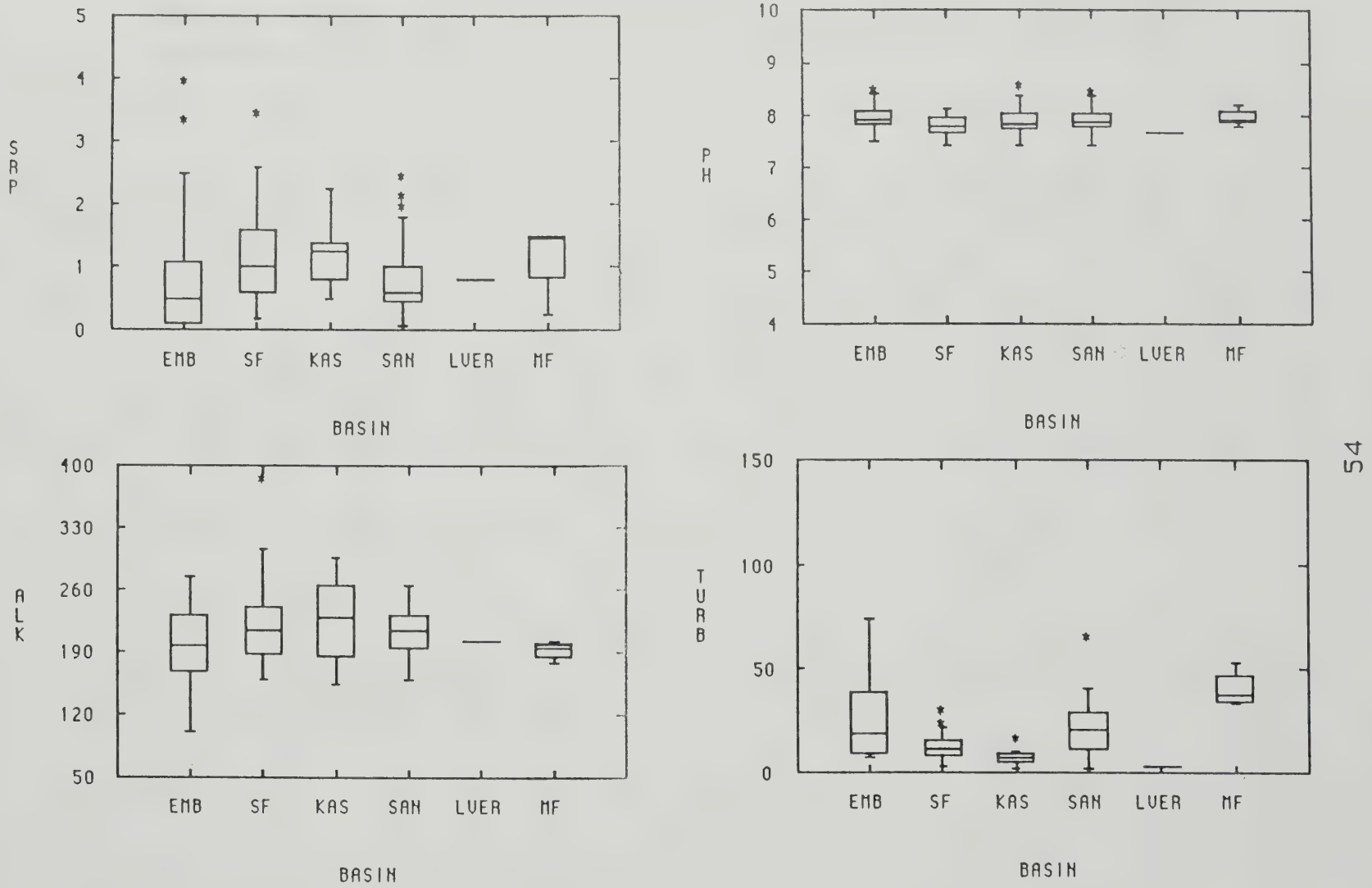


Figure 101.2.15. Box plots of mean soluble reactive phosphorus (mg/l), alkalinity (mg/l), pH, and turbidity (NTU's) at 1987 sampling stations in each major drainage basin in Champaign County.

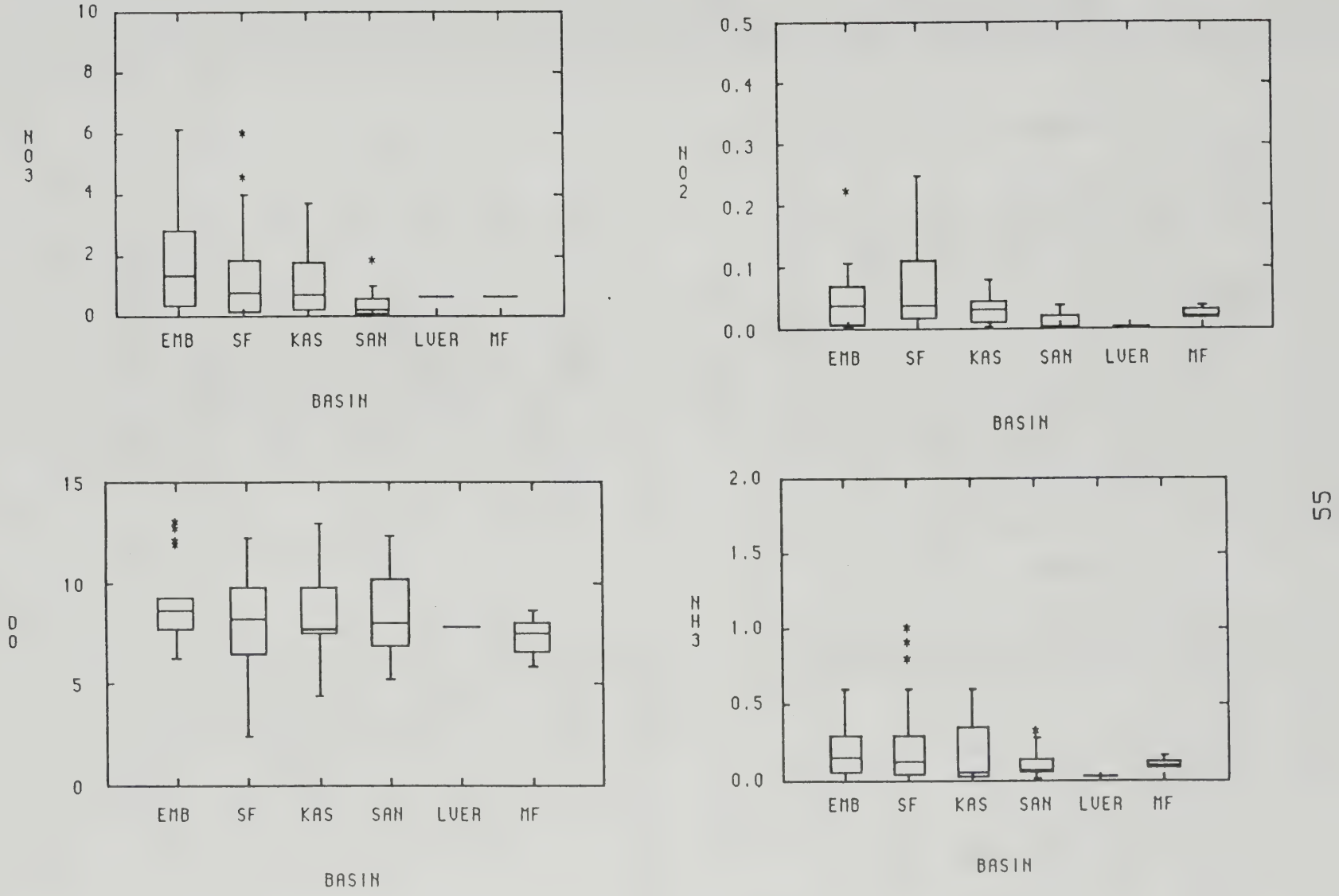


Figure 101.2.16. Box plots of mean nitrate-N (mg/l), nitrite-N (mg/l), ammonia-N (mg/l), and turbidity (mg/l) at 1987 sampling stations in each of the major drainage basins of Champaign County.

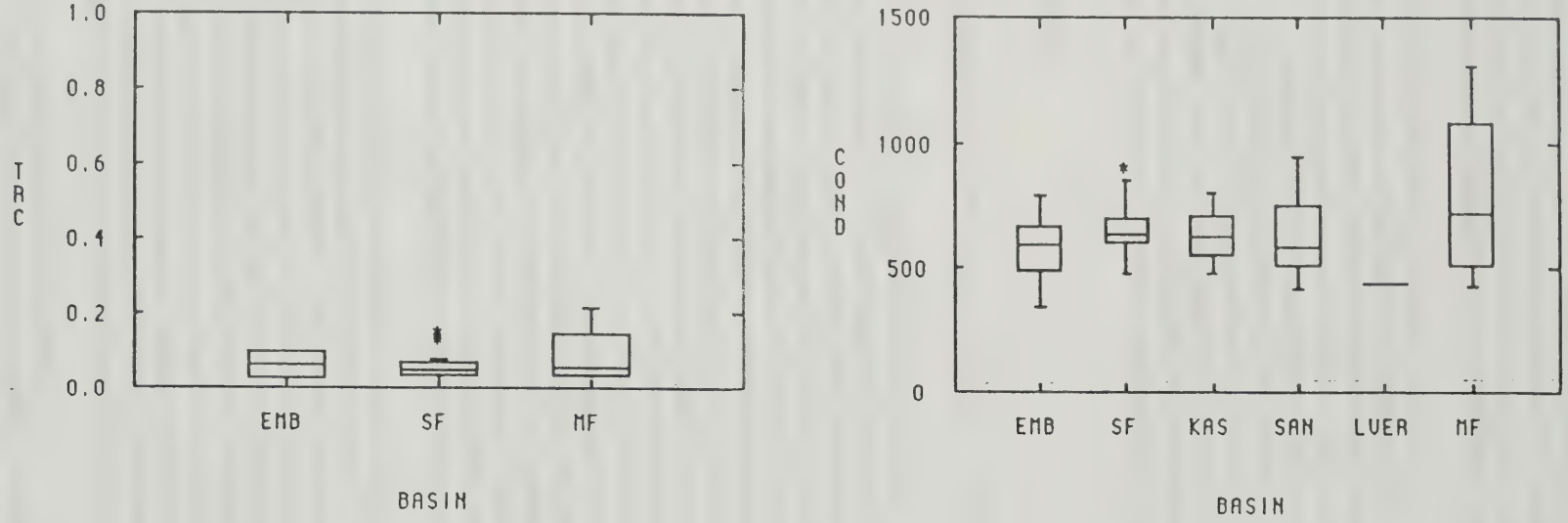


Figure 101.2.17. Box plots of mean total residual chlorine (mg/l) concentrations and specific conductance (umho's) at 1987 sampling stations in major drainage basins of Champaign County.

The lack of variation in the Little Vermilion basin plots reflects the fact that data were collected at only one station within the basin in 1987. Additional stations were sampled in 1988. All other basins were represented by at least 10 sampling stations (see Osborne et al. 1989 for details on sampling stations).

Examination of the box plots of physical habitat parameters (Figures 101.2.9 - 101.2.17) reveal several pertinent characteristics of the streams in Champaign County. In general, there were minimal differences among stations across basins in most parameters examined. An obvious exception was the higher average total stream width at stations in the Middle Fork basin compared to stations in other basins (Figure 101.2.11). This higher width value reflects the fact that the Kaskaskia, Embarras, Little Vermilion, the Salt Fork, and a significant portion of the Sangamon basin originate in the county and are composed of smaller, low-order streams. The Middle Fork originates north of Champaign County and is a mid-order stream when it enters the county. An additional difference observable in the data is the slightly higher turbidity of the Middle Fork system.

The most obvious characteristic of these streams was the limited variability in the parameters themselves, reflecting the homogeneous nature of stream habitat conditions within the county. For instance, the stream side cover ratings displayed little or no variation at stations in the Kaskaskia or the Embarras basin (Figure 101.2.11). The limited degree to which banks are undercut reflects the channelized and manicured nature of most smaller streams in this area. This lack of variation is reflective of the dominance of row-crop agriculture in the county. A further indication of the influence of agriculture on the streams is the consistently high nutrient concentrations (Figures 101.2.16 and 101.2.17). This lack of variability is further reflected by the lack of distinct groupings in the cluster analysis dendrogram (Figure 101.2.18). This dendrogram was based on uncorrelated physical, chemical, and riparian landuse data collected in 1987, prior to the 1988 drought. The data were standardized prior to clustering (Euclidean distances, single linkage). All but one station, station 1044 located in the Salt Fork basin are represented in the dendrogram. Station 1044 was the sole member of a group that was different from all other stations. This difference was due to an inordinately deep undercut bank. Other than this aspect, it appeared to be similar to other sampling stations.

FISH COMMUNITY-ENVIRONMENTAL PARAMETER RELATIONSHIP

METHODS

To assess the influence of physical and chemical habitat parameters on the structure of fish communities a matrix of uncorrelated and standardized environmental variables (station by environmental variable) was developed. Sampling stations were assigned to one of six groups (Table 101.2.7). Stations were assigned to groups on the basis of a cluster analysis (Wilkinson 1989) that used fish presence-absence data from 101 stations sampled in 1987. A Jaccard similarity coefficient (see Gower 1985) was calculated for each pair of stations and the resulting station by station matrix clustered using the complete linkage algorithm and Euclidean distance measures (Wilkinson 1989). A total of 81 taxa of fish were used in developing the presence absence matrix. These fish represented the list of taxa collected among the 101 stations sampled.

The resulting station groupings were subsequently used to categorize station environmental data using multiple discriminant analysis (MDA; Wilkinson 1989). The purpose of this analysis was to identify those environmental parameters that accounted for the majority of the variance among the station groups in Table 101.2.7. The initial list of environmental

Station Dendrogram Based Upon
Clustering of Environmental Variables

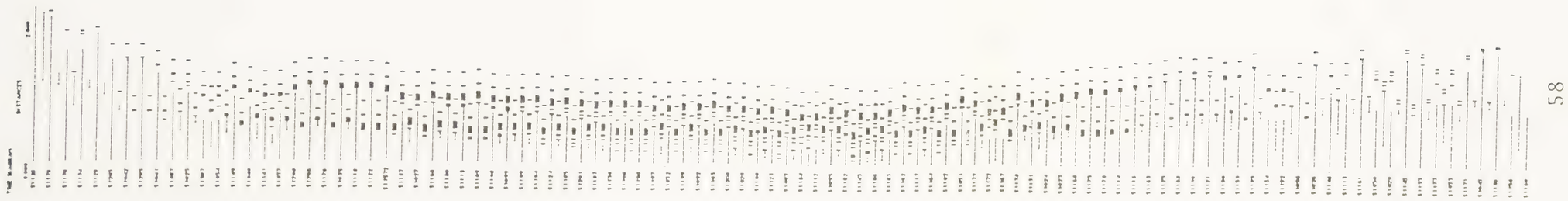


Figure 101.2.18. Dendrogram of Fishes of Champaign County stations sampled in 1987 based upon clustering of environmental variables.

Table 101.2.6. The station groupings generated using cluster analysis on the 1987 fish presence- absence data.

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
1106, 1199,	1093, 1043,	1184, 1197,	1117, 1040	1112, 1134,	1035, 1030,
1026, 1114,	1099, 1044	1163, 1185,		1125, 1122,	1034, 1033,
1188, 1100,	1113, 1041,	1178, 1165,		1121, 1109,	1145, 1157,
1186, 1097,	1092, 1095,	1187, 1172,		1123, 1195,	1146, 1507,
1024, 1139,	1042, 1102,	1118, 1131,		1206, 1208	1167, 1037,
1190, 1027	1143, 1196,	1107, 1116,			1141, 1171,
	1200, 1198,	1108, 1130			1177, 1193,
	1115, 1032,				1156, 1159,
	1138, 1025,				1176, 1161,
	1023, 1031,				1194, 1149,
	1028, 1205,				1160
	1128, 1129,				
	1201, 1110,				
	1124, 1164,				
	1170, 1169,				
	1168, 1180,				
	1179, 1175				
	1162, 1174,				
	1166, 1182,				
	1203, 1183,				
	1029, 1096				

parameters used in the MDA consisted of uncorrelated environmental parameters in fourgeneral categories: water chemistry, inchannel habitat, riparian land use, and basin scale parameters. The water chemistry parameters included ammonia-N, soluble reactive phosphorus (SRP), turbidity, and specific conductance. Physical habitat parameters included mean station depth, coefficient of variation in station velocity, percent channel vegetative cover, left and right bank undercut, and percent total shading. Riparian land use parameters included percent right bank buffer crop (PRBC), percent right bank corn (PRC), hay (PRH), oats (PRO), pasture (PRP), soybean (PRS), and urban land (PRU), and percent left bank urban land (PLU). Basin scale parameters included the total drainage area of the sampling station and the drainage basin affiliation (e.g., Sangamon, Salt Fork, etc.).

Preliminary analyses indicated that six of the riparian land use parameters (PRH, PRO, PRP, PRS, PRU, PLU) were not significantly different across station groupings in univariate analyses. Therefore, these parameters were eliminated from the final MDA.

RESULTS

Station Groupings

A total of six station groups resulted from the cluster analysis on the fish presence-absence data. Examination of the basin affiliation of stations within individual clusters revealed that the six station groupings did not clearly correspond to drainage basins (Champaign County) (Table 101.2.7). All station groupings consisted of stations from at least three drainage basins except Group 4 which only contained two stations, each from a different drainage basin. Group 1 was dominated by Salt Fork River and Embarras River stations. Group 2 was dominated by Salt Fork River, Embarras River, and Sangamon River stations; Group 3 by Kaskaskia River, and secondarily by Salt Fork River and Sangamon River stations. Groups 5 and 6 were dominated by Sangamon and Kaskaskia Rivers and the Sangamon River, respectively.

Group 2 was the largest group, containing 45% of the total number of stations. Average fish species richness at Group 2 stations was 15.2 ± 3.8 and ranged from 9-27 species. This large number of stations from a wide array of drainage basins, and stream sizes categorized into a single Group reflects the general similarity in fish communities within the county. Group 6 had the highest average species richness (19.1 ± 5.6) and was largely composed of mid- to large river stations. Groups 1 and 3 generally consisted of small streams but averaged substantially different species richness values. Stations in Group 1 averaged only 7.4 taxa per station while those in Group 3 averaged 12.4 taxa. This difference in average species richness among these similar sized streams suggests that communities at stations in Group 1 were more stressed than were communities at stations comprising Group 3. Group 5 consisted largely of mid-size streams (Table 101.2.7) and averaged 10.9 ± 3.1 species. Group 4, consisted of only two stations, and averaged only 6.5 species per station (range 6-7). The separate categorization of these two stations from other stations suggests that their fish communities were unique for some reason. In summary, although observed species richness was not used in this analysis, the grouping reflected this measure.

Environmental Discriminant Functions

All multivariate tests were significant at $\alpha = 0.05$ when the 14 uncorrelated environmental parameters were included in MDA. Because we only used stations without missing values in our MDA procedures, only 84 of the original 101 sampling stations belonging to the six station clusters were incorporated in the development of the final five discriminant functions (Table 101.2.8). Of these stations, MDA properly categorized 73% of the Group 1 stations, 45% of the Group 2 stations, 58% of the Group 3 stations, 100% of the Group 4 stations, 71% of the Group 5 stations and 80% of the Group 6 stations. Given that these are species presence-absence data and the sampling stations are subject to multiple stresses, such ranges in station categorizations are quite reasonable.

MDA generated five individual discriminant functions (Table 101.2.8). Each discriminant function (DF) is composed of all of the uncorrelated environmental variables entered into the analysis. The degree to which each environmental variable influences a DF is reflected in the magnitude (either positive or negative association) of the standardized coefficient scores. The environmental variables with the highest absolute coefficients are also the variables that have the greatest influence on a single DF axis. For instance, a group of

Table 101.2.8. Principal environmental variables associated with each discriminant function (DF) and their associated standardized coefficients. R.B. = Right bank.

DF 1	Standardized Coefficient	DF 2	Standardized Coefficient
Specific Conductance	0.669	Drainage Area	-0.941
Mean Depth	-0.398	% R.B. Buffer Cover Crop	0.514
Drainage Area	0.275	Soluble Reactive Phosphorus	0.469

DF 3	Standardized Coefficient	DF 4	Standardized Coefficient
Basin	-1.220	R.B. Undercut	0.618
Mean Depth	-0.673	Total Shade	-0.524
Total Shade	0.666	Soluble Reactive Phosphorus	0.441

DF 5	Standardized Coefficient
Specific Conductance	-1.143
Turbidity	1.039
% R.B. Corn Crop	0.665

stations separated from other station groups along the DF 1 axis (Table 101.2.8) would be distinguished from one another on the basis of specific conductance, depth, and drainage area. The most influential environmental variables comprising each of the five generated DFs are reported in Table 101.2.8.

Insights into the environmental parameters responsible for the classification of stations with similar fish communities into separate groups (Table 101.2.7) can be obtained by plotting the standardized coefficents of the environmental variables from each station (letters designating their group affiliation) along pairs of DF axes (e.g., Figures 101.2.19 - 21). For instance, when the stations in Table 101.2.7 were plotted in relation to DF 1 and DF 2

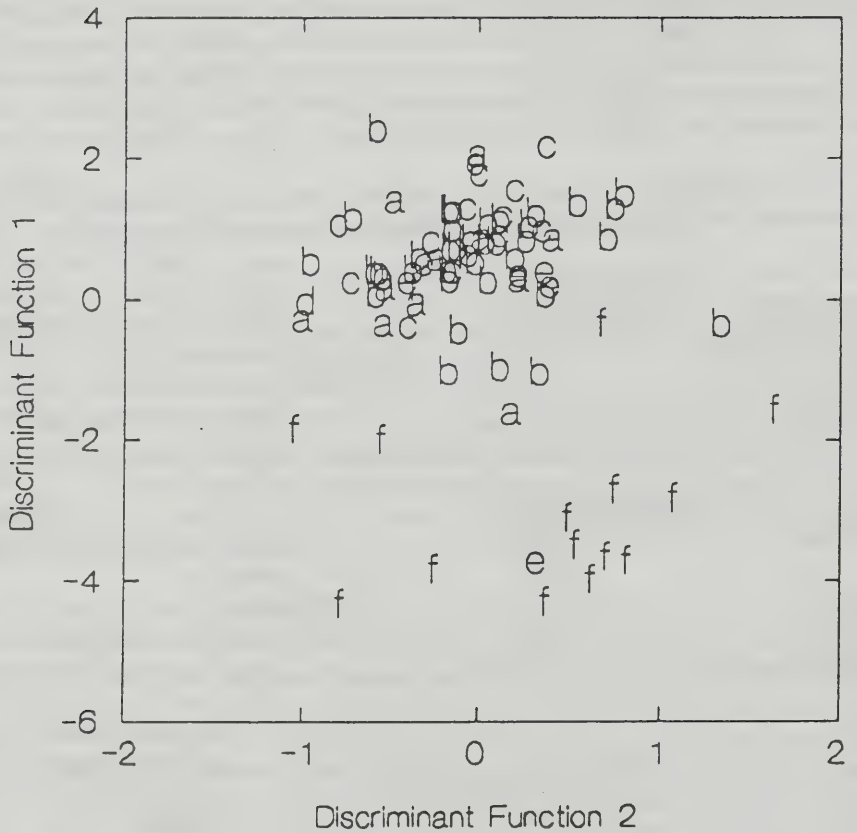


Figure 101.2.19. Station groups generated using cluster analysis (see text for details) plotted in discriminant space with resect to DF1 and DF2.

axes, the stations comprising Group 6 (letter f in Figure 101.2.19) became more distant from the other stations. The Group 6 (or f) stations had lower DF 1 coefficients and slightly higher DF 2 coefficients (Figure 101.2.19). Examination of Table 101.2.8 indicates that the DF 1 axis was largely comprised of specific conductance, drainage area and mean depth. The DF 2 axis was comprised of drainage area, proportion of buffer crop and soluble reactive phosphorus concentration. The stations comprising Group 6 had the highest mean specific conductance, a high mean depth, and had the largest drainage areas. These factors are characteristic of larger river systems. Thus, these results indicate that the assemblage of fishes at stations in Group 6 (Table 101.2.7) differed from the assemblage of fish at other stations and that the difference was largely attributable to a larger river like environment. These systems had higher mean depth, and more fully developed floodplains thereby accounting for the low proportion or negative association with buffer crops.

Using a similar procedure we can attempt to identify the environmental parameters responsible for the categorization of the other station groups in Table 101.2.7. Group 2 (b), the largest cluster of stations, was moderately distinguishable from other station groups on the basis of higher SRP concentrations, fairly low total shading, and a greater degree of undercut banks (Figure 101.2.20). Similarly, some discrimination of Group 3 (c) from other station groups was apparent along axes DF 3 and DF 4 (Figure 101.2.21). Stations in this group were characterized by relatively high total shading, low mean depth, and low SRP concentrations. Much of the total shading however, appears to be associated with the steep, channelized banks as opposed to the development of riparian vegetation. Also, the majority of these stations occurred in either the Embarras or the Salt Fork drainage. Although the mean depth was fairly low among the Group 3 stations (11.9 cm) it was even lower among the Group 1 stations (8.3 cm). These data suggest that the higher mean species richness at stations comprising Group 3 relative to those at the similar sized Group 1 stations may be associated with the differences in depth as few other environmental factors varied. No other discrimination of station groupings could be observed in the 2-dimensional plots.

Overall, these results suggest that stream size, mean depth, total shading, percent buffer crop, and nutrient concentrations are associated with the major differences in stream fish communities among sampling stations in Champaign County. From a management perspective, little can be done to control, or, to influence factors associated with stream size. Further, the unstable and persistently shifting substrata, in association with the high sediment loads in this region will make it difficult to alter channel depth. Providing for the development of a natural sinuosity as opposed to maintenance of very straight and constrained channelized conditions could, however, permit development of deeper pools along stream channels. High nutrient concentrations are associated with increased rates of primary production and diel fluctuations in dissolved oxygen concentrations in midwestern streams (Wiley et al. 1990) which can adversely impact stream fish communities. Control of instream nutrient concentrations requires both reductions in inputs within the watershed and implementation of corridor and/or riparian mitigation control strategies (Osborne and Herricks 1989) both of which can be achieved through reasonable watershed management programs. Finally, incorporation of buffer crops to reduce surface and subsurface inputs of nutrients to streams (Kovacic et al. 1990, Osborne 1989) and planting of vegetation to increase stream shading and thus, reduce inchannel primary production (Wiley et al. 1990) are added tools available to stream managers. The problem in Illinois, of course, is access to, and control over the riparian corridor. Nonetheless, these data suggest the structure of stream fish communities can be altered to at least a moderate extent, by resource managers through manipulation of key environmental variables such as total shading, riparian buffer strips of cover crops, alterations in nutrient inputs, and modification of channel depths by allowing sinuosity to develop.

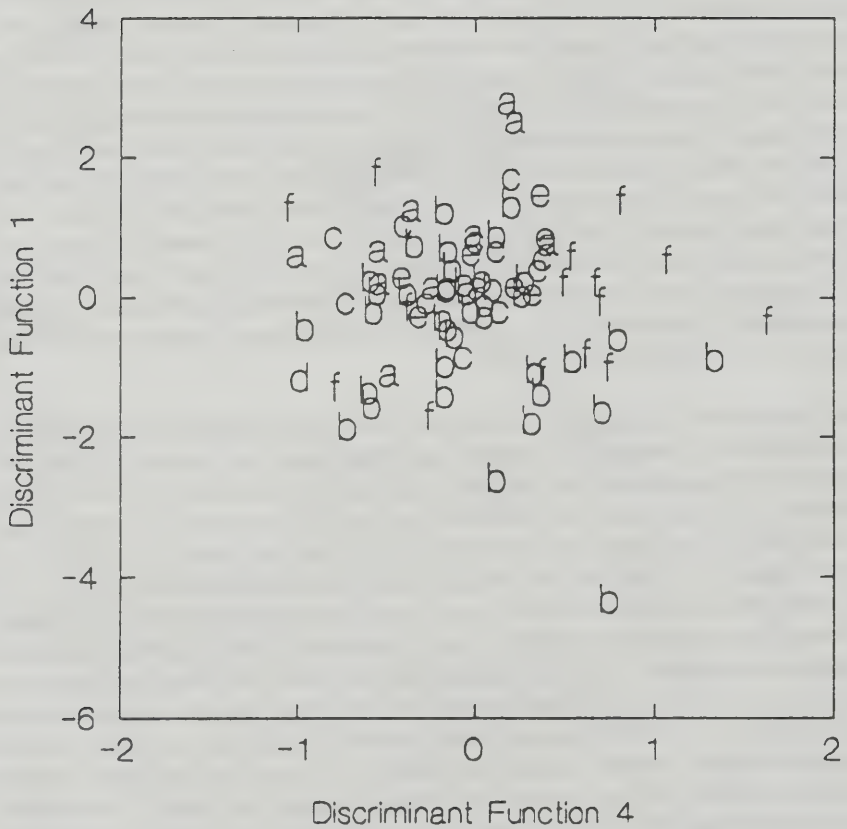


Figure 101.2.20. Station groups generated using cluster analysis (see text for details) plotted in discriminant space with respect to DF1 and DF4.

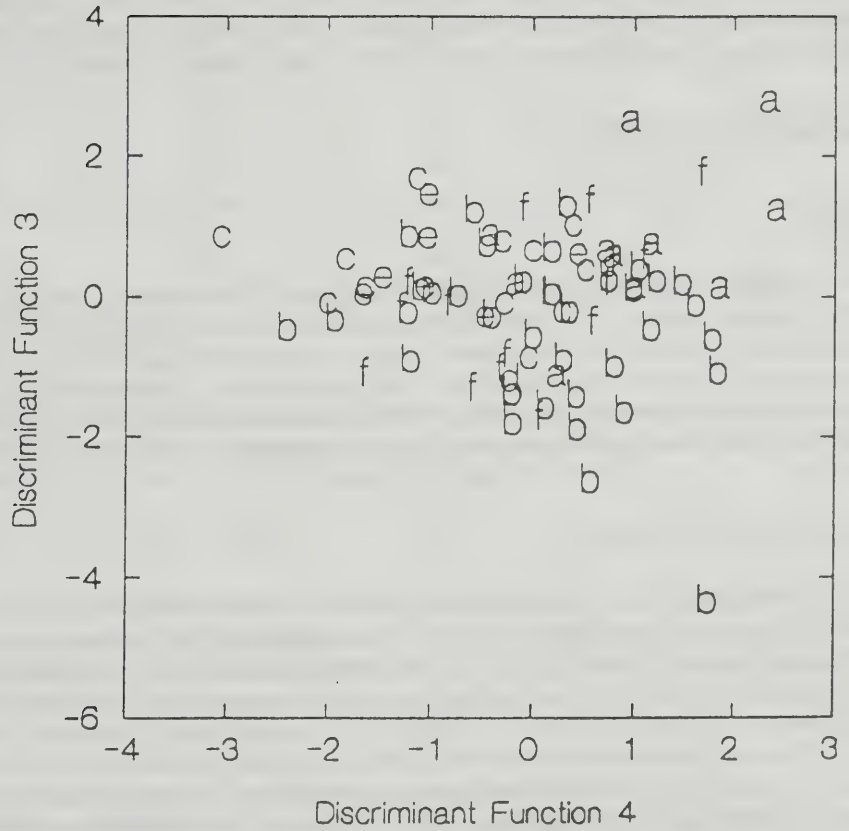


Figure 101.2.21. Station groups generated using cluster analysis (see text for details) plotted in discriminant space with respect to DF3 and DF4.

JOB 101.3. SPORT FISH: FOOD SUPPLY AND HABITAT

The primary objectives of this job were to evaluate changes in sportfish populations (particularly those of smallmouth bass) in a Champaign County watershed by surveying food supply, water quality, and habitat distribution and to prioritize controlling factors that may provide a basis for mitigation or restoration procedures. Physical and chemical habitat and riparian land use sampling methods were described in Job 101.2. Below we present methods of macroinvertebrate and crayfish sampling procedures. These methods were used to assess the abundance of macroinvertebrate prey items in one of the major drainage basins, the Vermilion River basin. An additional focus of Job 101.3 was to determine the primary food of the major sport fish in the Vermilion River. Prey abundance data, along with the physio-chemical habitat data were related to the density of sportfish populations in an attempt to assess principal factors controlling the distribution of sportfish.

FISH STOMACH ANALYSIS

METHODS

We initially attempted to obtain representative samples of the stomach contents of fish using pulse gastric lavage (Foster 1977) and thereby avoid the necessity of sacrificing fish. As reported in Osborne et al. (1990) we found that the lavage technique did not provide an unbiased sample of the stomach contents of grass pickerel and a substantial portion of the rock bass and smallmouth bass examined. We therefore abandoned the lavage technique and reverted to direct removal of preserved stomach contents. This, unfortunately required sacrificing fish.

Acquisition of Stomach Contents

A total of 115 stomachs from four species of fish (19 Channel catfish (CCF), 30 Rock bass (ROB), 24 Small-mouth bass (SMB), and 35 Grass pickerel (GRP)) were obtained from twelve sampling stations (Table 101.3.1). Fish were obtained during standard fish sampling (see earlier section) and were therefore daytime samples. Total length and total weight were measured and the stomach contents were immediately preserved in one of three ways. The most common method was applied to small predators, in which the entire fish was placed into 10% formalin immediately after capture. In the second method, the body cavities of larger fish were injected with concentrated formalin before being stored in 10% formalin. The final method consisted of removing the intestine and stomach from large fish and placing these directly into 10% formalin until processing. Because it is unlikely that these differences in preservation influenced the results, subsequent data analyses did not consider methods of preservation.

In the laboratory, the contents of the anterior quarter of the intestinal tract and the entire stomach of each specimen were removed and the total volume determined by displacement to the nearest 0.1 ml using a 100 ml graduated cylinder. The contents were sorted and individual items assigned to one of four broad categories: 1) Vegetation/ Detritus (VD), 2) Invertebrate (I), 3) Fish (F), and 4) Crayfish (C). The percentage contribution of each prey category to the total stomach volume (displacement of water) was estimated and recorded. Animal contents were identified to the lowest practical taxon and enumerated. The percent contribution of each prey item (taxon) to the total number of items (taxa), excluding plant/detritus, was determined separately. The length of the crayfish chela, as well as the total length of all identifiable fish were determined to the nearest 0.1 mm.

Table 101.3.1. The number of fish of each species used for stomach content analysis and the location from which they were collected.

Station	Channel Catfish	Rock Bass	Smallmouth Bass	Grass Pickerel
INHS-33D	0	0	5	0
INHS-95	0	0	0	6
JORD2002A	0	0	1	1
JORD2002B	0	0	1	0
JORD-2008	0	0	0	9
JORD-2027	0	0	0	9
JORD-0903	0	22	6	8
JORD-0906	0	1	0	0
SALT-1	3	2	0	0
SALT-3	2	1	7	0
SALT-6	0	2	0	2
SALT-10	14	2	4	0
Totals	19	30	24	35

Stomach Content Analysis

Interspecific overlap in the mean percent abundance and the percent volume of general prey categories and specific prey items within the stomachs of the four species of fish were determined using Schoener's (1968) index (R_O) defined as:

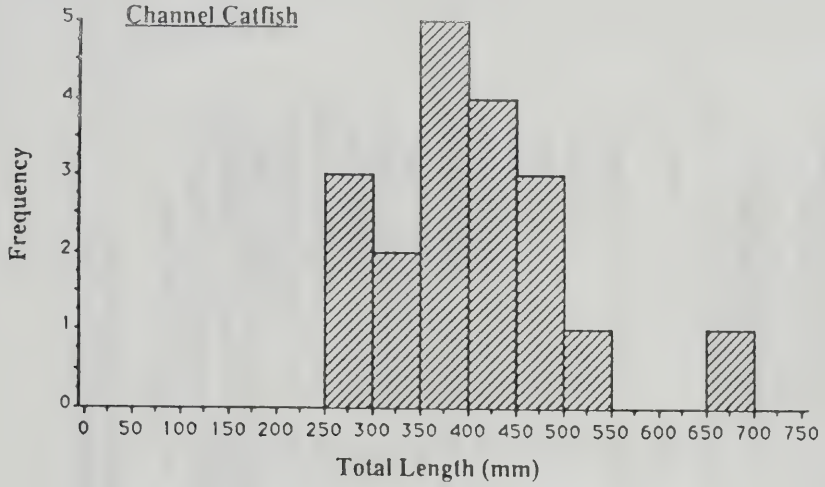
$$R_O = 1 - 1/2 \sum | p_{ij} - p_{ik} |$$

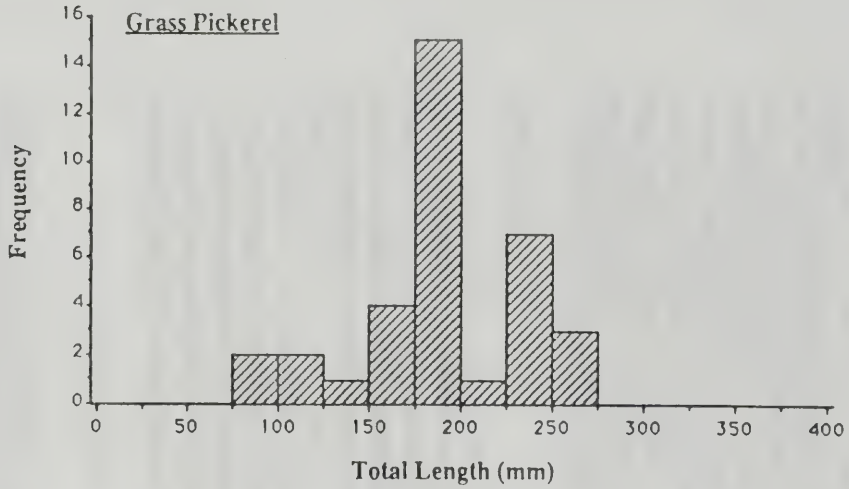
where p_{ij} and p_{ik} are the intensity of use of the ith resource (prey item) by the jth and kth species. Percent abundance of stomach items did not include plant material because of the obvious problems associated with enumeration. Volume estimates included plant and animal materials. General prey categories included plant material, invertebrates, fish, and crayfish.

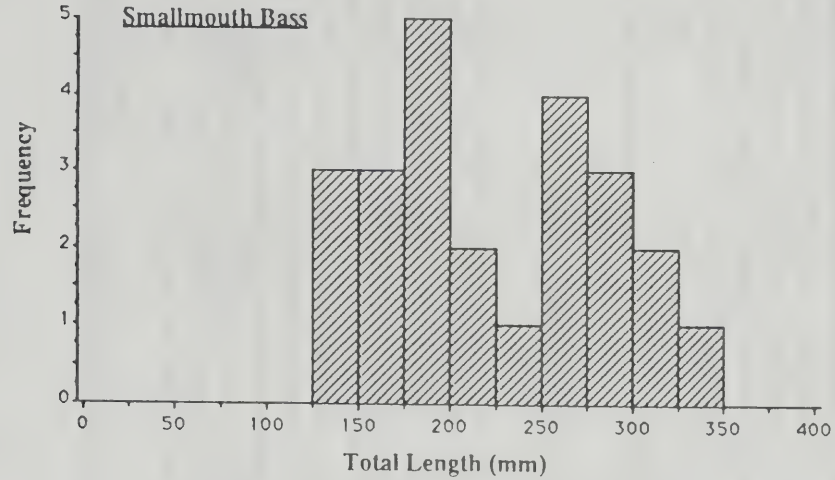
Estimates of the original size (weight) of ingested crayfish were determined from allometric relationships between live crayfish weight (g) and chela length (mm) of each crayfish species. Differences in the size of crayfish ingested by each fish species were determined using an analysis of variance (Wilkinson 1989).

RESULTS

A limitation of this study was that the stomach contents of fish were only collected during the daylight period. An earlier study in central Illinois demonstrated that several of these fish species were crepuscular in their feeding activities (e.g., Osborne et al. 1988). Although nocturnal collections were not made in the present study, we did collect fish for stomach analyses from approximately 0700 hr to 1800 hrs, which should provide a reasonable representation of prey items consumed. A further limitation of these results is that only the stomach contents from adult fish were examined (Figure 101.3.1). Thus, we do not provide information on the prey consumed by young or immature stages of each species.







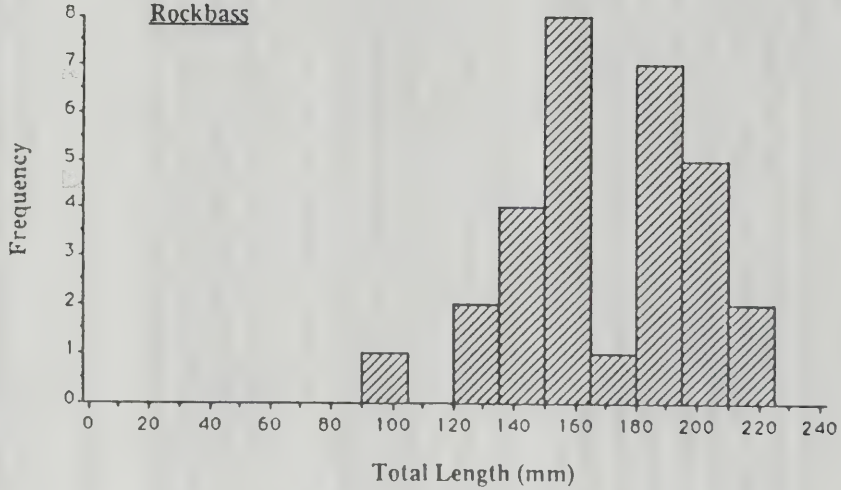


Figure 101.3.1. Size frequency distribution of the four species of fish used in the stomach content analysis. Note differences in scales.

Based on resources utilization indices of the percent stomach volume of general prey categories (i.e. macroinvertebrates, fish, and crayfish) the diets of grass pickerel, rock bass, and smallmouth bass were very similar (Table 101.3.2). Conversely, resource utilization indices for channel catfish with the other three fish species were very low which reflects the high content of algae in the stomach (Table 101.3.3). The resource overlap indices based on percent abundance of animals in stomachs between grass pickerel, rock bass, and smallmouth bass were also high while those contrasting channel catfish with the other three species substantially increased (Table 101.3.2).

Table 101.3.2. Schoener's index of interspecific diet overlap (general categories of prey items) among channel catfish, smallmouth bass, Rock bass, and grass pickerel. a) is based on the mean percent volume of each major category found in the stomach of each species. b) is based on the mean percent abundance of animal prey in the stomach of each species.

a. Indices Using Mean Percent Volume of Each General Prey Category

	Grass Pickerel	Smallmouth Bass	Rock Bass	Channel Catfish
Grass Pickerel	-			
Smallmouth Bass	0.85	-		
Rock Bass	0.94	0.89	-	
Channel Catfish	0.11	0.10	0.10	-

b. Indices Using Mean Percent Abundance of Each General Prey Category

	Grass Pickerel	Smallmouth Bass	Rock Bass	Channel Catfish
Grass Pickerel	-			
Smallmouth Bass	0.86	-		
Rock Bass	0.88	0.85	-	
Channel Catfish	0.39	0.34	0.49	-

Of the fish examined, 18 grass pickerel (51%), 22 smallmouth bass (92%), 25 rock bass (83%), and 18 channel catfish (95%) contained at least one of the 78 individual prey items identified in the stomachs of the four fish species (Table 101.3.3). Channel catfish had the widest range of prey items in their stomach (37 different taxa) while grass pickerel had the least (14 taxa) (Table 101.3.3). On the average aquatic vegetation, primarily Cladophora spp., constituted more than 89% of the volume of the stomach contents of channel catfish while invertebrates and crayfish comprised 4.4% and 3.5% of the average volume respectively (Table 101.3.3). Crayfish constituted the greatest proportion of the volume of the stomach contents of grass pickerel, smallmouth bass, and rock bass, accounting for

Table 101.3.3. Percent of the total volume of each prey item found in the stomachs of channel catfish, grass pickerel, rock bass, and smallmouth bass.

Prey	Percent of the Total Volume for Channel Catfish	Grass Pickerel	Rock bass	Smallmouth bass
Aquatic Vegetation	89.51	1.3		0.029
Terrestrial Vegetation	1		0.03	
Tubellaria	0.03			
Oligochaeta	0.1			
Diploploda	0.01			
Nematoda			0.23	
Hymenoptera			0.145	
Formicidae			0.258	
Ephemeroptera		6.3	0.024	
Siphlonuridae				0.38
Baetis spp.	0.02			
Heptageniidae				0.18
Stenacron spp.				0.24
Ephemerella inermis	0.02			
Tricorythodes spp.	0.02			
Caenis spp.	0.13		0.056	
Potamanthus spp.			1.61	
Potamanthus myops	0.0024			
Hexagenia limbata		3		
Diptera			0.05	0.08
Chironomidae	0.88	0.3		
Simulidae	0.01			
Tipulidae			2.09	0.9
Tipula spp.				0.97
Antocha spp.				0.03
Muscidae				0.25
Odonata	0.0026		0.04	0.62
Coenagrionidae		0.2		
Cordulidae	0.006			
Terrestrial Coleoptera	0.0033		0.9	
Aquatic Coleoptera			0.7	0.55
Stenelimis spp.	0.013			
Helodidae	0.24			
Histeridae			0.17	
Hydroptilidae	0.0073			
Hydroptial spp.	0.03			
Orthotrichia	0.04			
Hydropsychidae	0.03		0.06	
Hydropsyche spp.	0.012		0.04	
Hydropsyche betteni				0.1
Hydropsyche bifida grp.	0.008			
Helicopsyche borealis			0.58	
Corixidae			1.2	
Nepa spp.		4		
Plecoptera	0.003			
Lepidoptera	1.525		1.9	1.28
Noctuiidae				1.09
Megaloptera	0.1			

Continued

Table 101.3.3 cont.

Prey	Percent of the Total Volume for Channel Catfish	Grass Pickerel	Rock bass	Smallmouth bass
Corydalidae				2.91
Corydalus spp.				0.9
Orthoptera	0.018		0.41	
Cambaridae	0.0023	1.91	1.44	3.8
Orconectes	0.36			
Orconectes propinquis	2.58	9.9	63.86	42.83
Orconectes virilis	0.69	46.31	7.78	9.07
Cambarus tenebrosus				15.42
Isopoda			0.23	
Asellus spp.		10.2		
Erpobdellidae	0.11			
Pleurocera spp.	0.1			
Sphaerium simile		5.96		
PISCES				
Esox americanus				2.43
Ambloplites rupestris			3.9	
Etheostoma spp.				6.2
Etheostoma blenniodes				2.91
Etheostoma caeruleum				1.27
Lepomis megalotis			1.9	
Micropterus dolomieui		5.96	1.24	
Nocomis biguttatus		13.24		
Cyprinidae	0.51			2.52
Notropis spp.				1.62
Luxilus chrysocephalus			0.65	
Notropis rubellus	1.04			
Notropis ludibundus			1.61	
Lythrurus umbratilis	0.03		1.61	0.5
Pimephales notatus	0.52		3.2	
Unidentifiable fish	0.72			0.93

approximately 59%, 56%, and 61%, respectively. Other invertebrates also comprised a substantial proportion of the stomach volume of grass pickerel (28%) and rock bass (24%) while fish constituted a substantial component of the stomach volume of smallmouth bass (26%) (Figure 101.3.2).

Similar to stomach volume, crayfish were the most numerically abundant prey in the stomachs of grass pickerel, smallmouth bass, and rock bass accounting for 58%, 48%, and 46% of the total items, respectively (Figure 101.3.2). Of the animals ingested by channel catfish, more than 91% were invertebrates, the majority of which were chironomids (Table 101.3.3) that were associated with aquatic vegetation (Osborne per obs.). Using these generalized stomach content data, we categorized grass pickerel, rock bass, and smallmouth bass as carnivorous with their primary prey consisting of crayfish (Figure 101.3.2). Channel catfish were categorized as herbivorous.

Using species level prey categories in the calculation of the resource utilization indices (Table 101.3.4) also demonstrated that channel catfish prey were quite different from the other three species examined. Unlike the previous analysis that used general prey categories, this analysis revealed as expected that the overlap indices of grass pickerel with

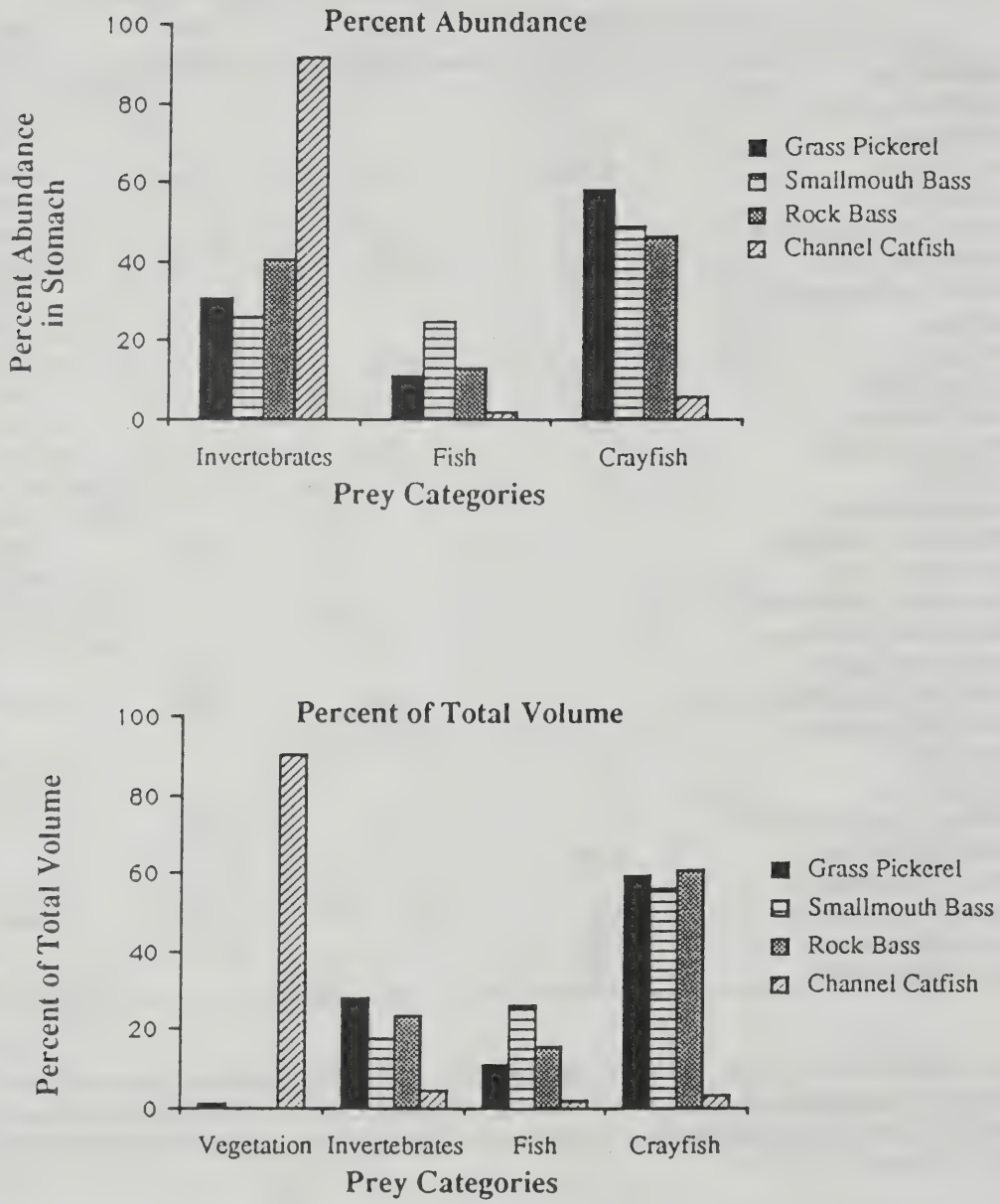


Figure 101.3.2. The mean percent abundance of each major animal prey category found in the stomachs of each of four species of fish and the mean percent total volume of the stomach contents belonging to each major prey category for each of the four fish species.

smallmouth bass and rock bass were substantially lower (Tables 101.3.2 and 101.3.4). While crayfish as a group, comprised a substantial proportion of the prey of all three of these species (Figure 101.2.2 and Table 101.3.3), the crayfish O. virilis was the dominant taxa found in the stomachs of grass pickerel, while O. propinquis was the most abundant crayfish in rock bass and smallmouth bass stomachs (Table 101.3.3) thereby accounting for the relatively high resource utilization index between these latter two species (Table 101.3.4).

Table 101.3.4. Resource utilization indices of stomach contents using the lowest taxonomic level to which prey items could be identified among channel catfish, smallmouth bass, rockbass, and grass pickerel. Data are based on the percent volume that each taxon contributed to the total volume of stomach contents for each species.

	Grass Pickerel	Smallmouth Bass	Rock Bass	Channel Catfish
Grass Pickerel	-			
Smallmouth Bass	0.16	-		
Rock Bass	0.17	0.57	-	
Channel Catfish	0.01	0.05	0.06	-

Although grass pickerel did co-occur with both smallmouth bass and rock bass at some stations, it was common for this species to occur in reaches where neither of the other two species were collected. For instance, grass pickerel were often found associated with undercut banks or overhanging grasses and weeds along the banks of smaller streams. Such reaches were characteristic of some headwater areas. Conversely, rock bass and smallmouth bass were more abundant in deeper pools shaded by a forested canopy. These general habitat characteristics were also consistent with the abundance pattern of the two crayfish O. virilis and O. propinquis which also displayed a somewhat allopatric distribution. O. virilis was unquestionably the most abundant crayfish in the open canopy headwaters while O. propinquis was commonly associated with stream reaches characterized by a fairly well developed riparian canopy. These distribution patterns in conjunction with the fact that both crayfish taxa were found in the stomachs of all three species of fish suggests that the fish are not partitioning crayfish prey on the basis of taxonomy, but rather, on the basis of their availability within habitats preferred by different predators. Alternatively, the fish may have been partitioning crayfish on the basis of their size. We tested this hypothesis by examining the relationship between the estimated size of crayfish consumed by each species (interspecific) and by examining the relationship between the sizes of crayfish consumed by different sizes of fish of the same species, as described below.

Estimation of the Size of Ingested Crayfish Prey

In 1987 and 1988 crayfish were collected from throughout the study area (see Crayfish Survey Section below), individuals were identified, pertinent morphological measures taken (e.g., chela length, carapace length, total length), and wet weights and dry weights determined in the laboratory. Because the scleritized crayfish chela were commonly found

in the stomachs of the target fish species, models relating the length of the chela to the dry weight of the crayfish were developed for each crayfish species. An analysis of covariance (Wilkinson 1988) indicated that there were no differences in dry

Table 101.3.5. Results of analysis of covariance on the effects of year (YR) on the ln(dwt) of A) O. virilis and B) O. propinquis with ln(chela) as the covariate. Preliminary testing demonstrated that the data met the criteria of homogeneity of slopes.

A) ANALYSIS OF VARIANCE TABLE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR	0.131	1	0.131	1.752	0.187
ln(CHELA)	275.370	1	275.370	3675.542	0.000
ERROR	19.629	262	0.075		

B) ANALYSIS OF VARIANCE TABLE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR	0.102	1	0.102	0.704	0.405
ln (CHELA)	49.072	1	49.072	339.864	0.000
ERROR	7.797	54	0.144		

weights of a crayfish species between years controlling for the effects of chela length (Table 101.3.5). Thus, crayfish data from 1987 and 1988 were pooled for subsequent analyses.

In comparing the chela length x dry weight relationship for O. virilis and O. propinquis we found no significant heterogeneity in the variance of the slopes between the regression lines of the two crayfish species (Table 101.3.6) suggesting that allometry relationships are consistent among the species (i.e., the rates of change in chela length and dry weights are not different). Species specific models were, however, developed independently for O. propinquis and O. virilis because an analysis of covariance on the dry weights of crayfish (species = treatment, covariate = chela length) demonstrated that there were significant differences (Table 101.3.7) in the size (dry weight) of the two crayfish species at a given chela length (Figure 101.3.3) .

The preceding analyses resulted in the development of models 1 and 2 (see below) for O. virilis (R^2=0.93, standard error = 0.274, N = 265) and O. propinquis (R^2 = 0.87, standard error = 0.379, N = 57), respectively.

$$\ln(\text{dry weight}) = -7.006 + 2.515 \ln(\text{chela length}) \quad (1)$$

$$\ln(\text{dry weight}) = -6.774 + 2.327 \ln(\text{chela length}) \quad (2)$$

Table 101.3.6. Results of an analysis of variance on the dry weights (natural logarithm) of the crayfish species O. virilis and O. propinquis with respect to ln transformed chela length. This tests the homogeneity of slopes assumption, prior to performing an analysis of covariance.

Source	SS	df	MSQ	F	P
Species	0.061	1	0.061	0.702	0.403
ln(Chela)	183.226	1	183.226	2107.065	0.000
Species * ln(Chela)	0.276	1	0.276	3.178	0.076
Error	27.659	318	0.087		

Table 101.3.7. Analysis of covariance on the dry weights (natural log) of the crayfish O. virilis and O. propinquis controlling for chela length (natural log).

Source	SS	df	MSQ	F	P
Species	2.904	1	2.904	33.159	0.000
ln(Chela)	326.876	1	326.876	3732.700	0.000
Species * ln(Chela)	27.935	319	0.088		

where, dry weight is in grams and chela length is in mm. These models were used to estimate the size of the crayfish ingested by individual fish species.

Because of the potential importance of food on the quality of sportfish populations we addressed two null hypotheses. The first was that within a like species there is no statistically significant relationship between the size of a fish and the prey it consumes. Secondly, we examined the hypothesis that there are no differences between the size of prey consumed among species which utilize the same prey items. Essentially, by testing the latter hypothesis we were addressing the question: do sportfish that co-occur and who have similar primary prey partition the prey resource on the basis of size.

In testing these hypotheses we restricted our analyses to only the major prey item (crayfish) consumed by each of the three species of interest (i.e., grass pickerel, smallmouth bass, and rock bass). The size of O. virilis and O. propinquis consumed by each fish was estimated using models 1 and 2 above. We only used data from fish where species level identifications of crayfish remains could be made because of the previously reported species specific crayfish allometric relationships. For these reasons, the number of actual comparisons that could be made were limited. Sufficient data were available to determine the relationship between the size of smallmouth bass and rock bass and the size of their major prey item, O. propinquis, to determine the relationship between grass pickerel and their major prey item O. virilis, and to test for differences in the size of O.propinquis consumed by smallmouth bass compared to those consumed by rock bass.

Results of Prey (Crayfish) Size Analysis

The average dry weight of the crayfish consumed by grass pickerel was estimated to be 0.420 g (s.e. = 0.199). Prey consumed ranged in size from 0.055 - 1.571 g. We found no significant relationship between the size of O. virilis consumed by grass pickerel and the size of grass pickerel ($R^2 = 0.15$, $p = 0.386$, $N=7$).

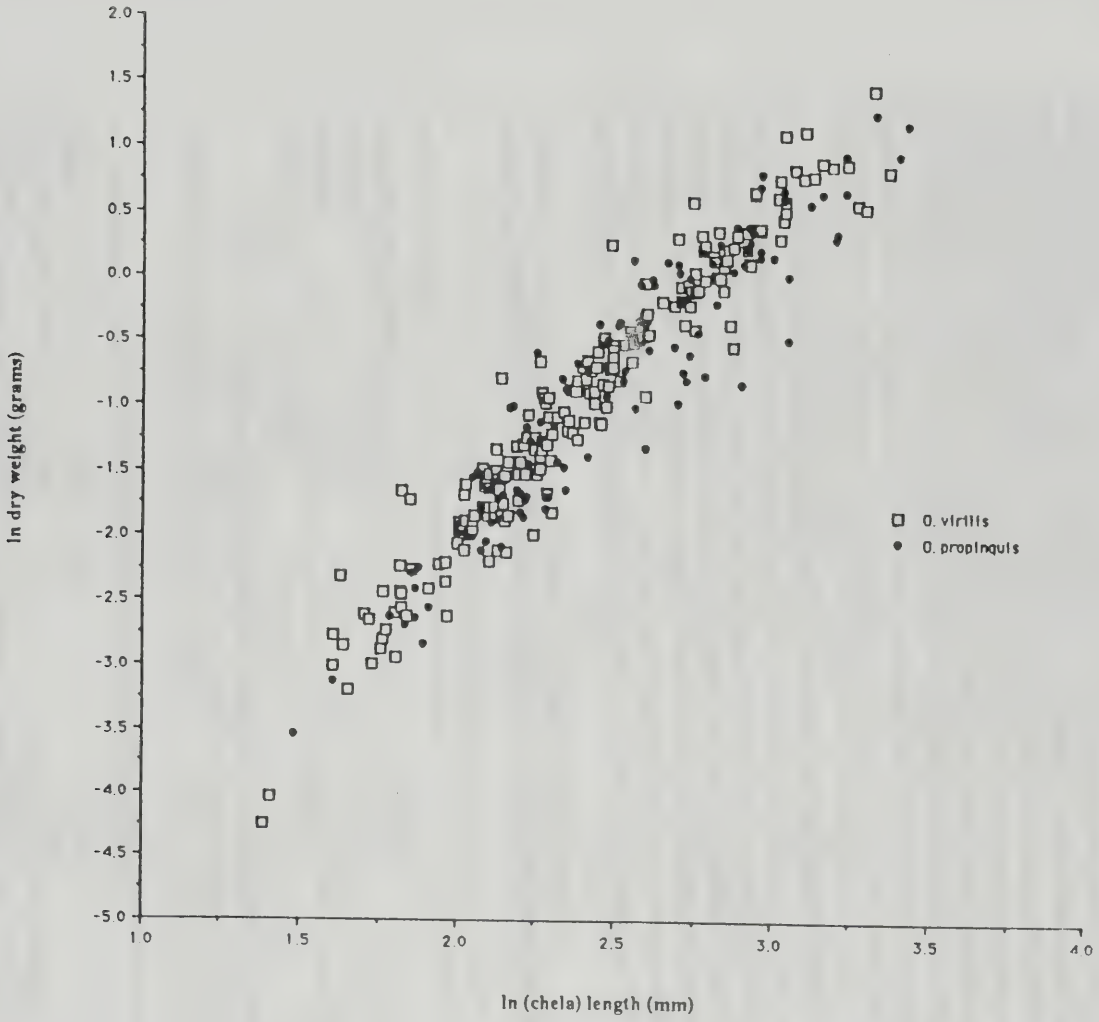


Figure101.3.3. The relationship between the natural log of chela length (mm) and the natural log of the dry weight (grams) for two crayfish species Orconectes virilis (open squares) and O. propinquis (closed circles) in east-central Illinois.

The average size of O. propinquis consumed by rock bass was 0.998 g (s.e. = 0.177). The dry weight of these prey ranged from 0.058 - 2.386 g, substantially less than the range of O. propinquis consumed by smallmouth bass (i.e., 0.113-4.244 g). The mean size of crayfish consumed by smallmouth bass (1.235 g, s.e. = 0.444) was also slightly larger than that consumed by rock bass. Unpaired t-test results contrasting the size of O. propinquis consumed by each of these species, however, demonstrated that there was no significant difference in the size of prey consumed ($p = 0.665$, $t = -0.438$, $N = 24$).

We found a significant positive relationship between the size of rock bass and the size of O. propinquis they consumed ($R^2 = 0.74$, $p = 0.0001$, $N = 17$) (Figure 101.3.4). This relationship was of the form:

$$\ln(wt) = -35.956 + 6.82 \ln(TL) \qquad (3)$$

where: wt is the weight in g of O. propinquis and TL is the total length (mm) of the rock bass predator. We also found a significant positive relationship between the size of smallmouth bass and the size of O. propinquis consumed ($R^2 = 0.61$, $p = 0.0136$, $N = 9$) (Figure 101.3.4). This relationship was of the form:

$$\ln(wt) = -16.194 + 2.92 \ln(TL) \qquad (4)$$

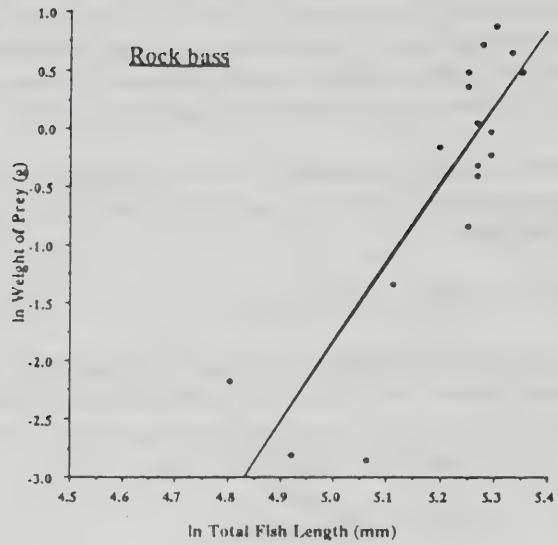
These results demonstrate a tendency for rock bass and smallmouth bass to select prey in relation to their size. Among other explanations, such a mechanism could minimize periods of resource limitation; alternatively, it may be an optimal foraging strategy whereby energy acquisition is maximized by consumption of the largest prey item available and that the fish is also able to handle. Additional, controlled experiments will be required to further elucidate the mechanism responsible for this observed pattern in prey size consumption.

In summary, we were unable to find evidence to indicate that rock bass and smallmouth bass partition their major prey items on the basis of the size of prey. Thus, within the systems examined, there is a potential for competition for food resources between rock bass and smallmouth bass. Of course for competition to occur, resources must be limiting to one or more of the predators. One indication of potential food limitation on a large scale is a negative relationship between prey densities and predator densities. We address this issue within the Vermilion River basin in a later section of this report.

CRAYFISH SURVEY

METHODS

Because of their hypothesized importance as a food resource to sportfish species, the distribution and abundance of crayfish species was assessed at 33 fish sampling stations (Figure 101.3.5) in the Vermilion River drainage in Champaign County from 28 July through 25 August 1987. In 1988, we also sampled 39 sites in spring (26 May-21 June) and 33 sites in summer (24 August-8 September), (Table 101.3.8). Summer samples in 1988 coincided with the height of the drought which will be addressed in Study 102 below. The relationship of crayfish densities to the abundance of sportfish at these stations will be addressed in the section "Factors influencing the abundance of sportfish".



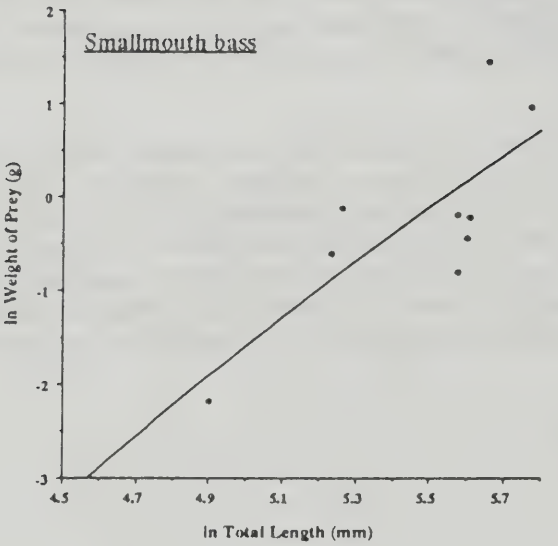


Figure 101.3.4. Relationship between the natural log of fish length and the natural log of the estimated dry weight of the crayfish Orconectes propinquis for Rock bass and Smallmouth bass.

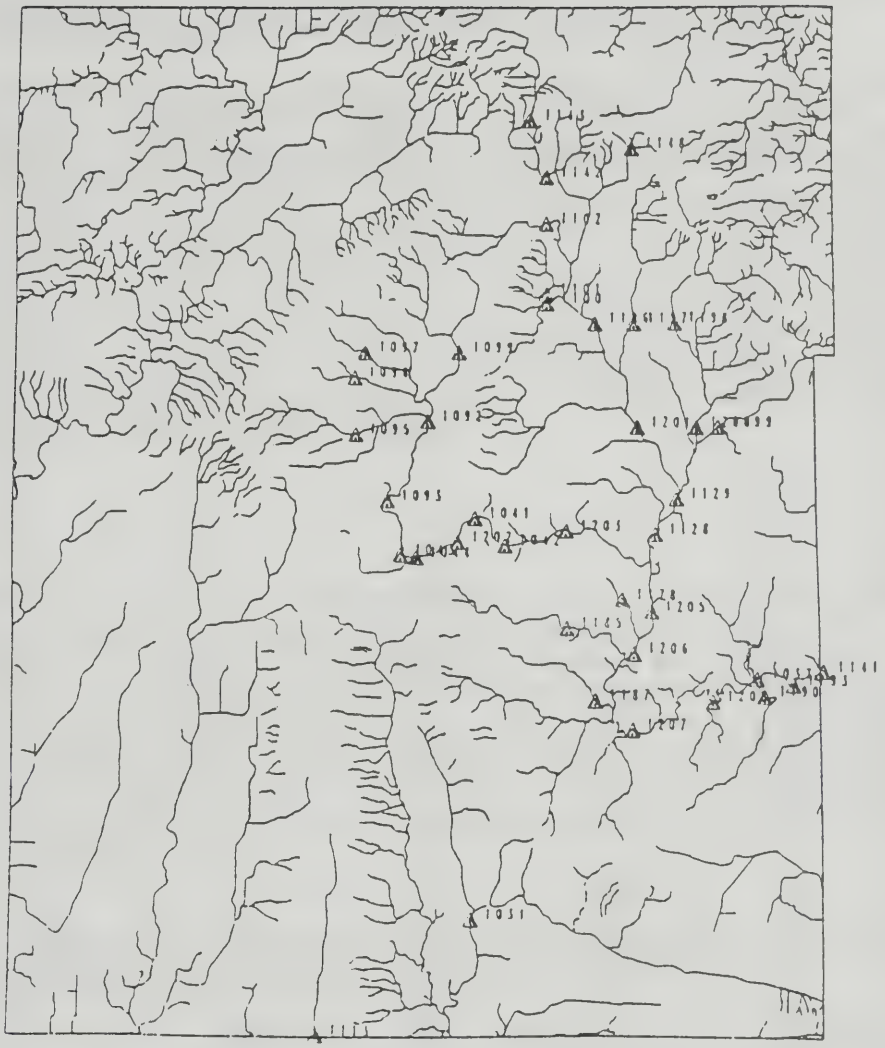


Figure 101.3.5. Stations where crayfish were sampled in the Vermilion River drainage.

Five samples were collected at each station using a 0.5 m^2 x 0.6 m high circular sampler. The crayfish sampler was placed firmly against the stream bed in habitats representative of the stations and crayfish were collected in the enclosure with a dip net. Sampling continued

Table 101.3.8. The density and species richness of crayfish at FCC sampling stations in summer, 1987; spring, 1988 (1988A); and summer, 1988 (1988B). NS = station not sampled.

Site	1987 #/m^2	1987 # taxa	1988A #/m^2	1988A # taxa	1988B #/m^2	1988B # taxa
1031	NS	NS	3.2	1	NS	NS
1037	1.6	1	2.8	2	0	0
1040	2.0	2	0.4	1	0.4	1
1041	0.4	1	2.0	2	1.6	2
1042	3.2	2	3.6	1	4.4	2
1043	2.4	2	0	0	0	0
1044	2.0	1	0.8	1	0.4	1
1092	2.0	1	0.8	1	0.4	1
1093	6.8	2	6.0	2	0	0
1095	10.4	2	17.6	2	3.6	1
1096	11.2	1	8.8	1	0	0
1097	0.4	1	0.8	1	0	0
1099	0.8	1	8.8	1	0.4	1
1100	1.6	1	11.2	2	0	0
1101	6.0	3	8.0	2	0	0
1102	19.2	1	40.4	2	0.4	1
1113	NS	NS	0.1	2	NS	NS
1128	0.4	1	0.4	1	0	0
1129	0.8	1	4.4	2	0	0
1141	0.4	1	0	0	3.2	2
1142	0	0	0	0	0	0
1143	2.0	1	2.8	1	0.8	1
1148	NS	NS	0	0	NS	NS
1178	NS	NS	1.6	1	NS	NS
1185	NS	NS	11.2	1	NS	NS
1187	1.2	1	4.4	1	0.4	1
1190	34.0	1	1.6	1	0	0
1193	1.2	1	1.2	2	1.6	1
1196	2.8	1	2.4	1	0	0
1197	10.4	3	37.6	2	3.6	1
1198	1.6	1	0.8	1	2.4	2
1199	5.2	2	3.2	1	0	0
1200	1.6	1	5.2	2	0.4	1
1201	0.8	1	0	0	0.8	1
1203	3.6	2	12.0	2	0.4	1
1205	0	0	0.8	2	0	0
1206	NS	NS	2.4	2	NS	NS
1207	0	0	0	0	0.4	1
1208	0	0	NS	NS	0.4	1

90°C for 24 h) were determined for each individual to the nearest 0.1 milligram on a Mettler H-80 balance.

until no crayfish were captured on five consecutive dippings. Samples were preserved in 7% formalin and returned to the laboratory for identification and morphometric measurements. Chela length, carapace length, and total length of each animal were recorded following identification. Wet and dry weights (determined by drying samples at

Morphometric Relationships

Information on ingestion rates, caloric content of prey, and size of prey consumed versus those available are fundamental to many aspects fish ecology including energy based growth models (e.g., Boisclar and Leggett 1990). Assessments of the size of prey consumed is commonly done on the basis of stomach content analysis. Often, however, only fragments of important prey items remain making it difficult to accurately estimate the size of prey consumed. To more easily determine the size of crayfish ingested by sportfish, we developed several relationships using linear regression models that relate the total length of the crayfish, the length of the carapace, and the length of the chela to the total dry weight of crayfish. These relationships were developed for the three species of crayfish for which sufficient data were available and included O. virilis, O. propinquis, and C. diogenes. In developing these relationships, crayfish collected from all three surveys (1987, 1988 spring and 1988 summer) were used.

RESULTS

A total of five species of crayfish were collected during standard sampling. These species included Orconectes virilis, O. propinquis, O. immunis, Procambarus acutus, and Cambarus diogenes. O. virilis and O. propinquis were the most widespread species (Figures 101.3.6 - 11) and constituted more than 97% of the total number of individuals collected during the study (Table 101.3.9). In 1987, crayfish were found at all but four stations sampled reflecting their cosmopolitan distribution in the Vermilion drainage basin (Table 101.3.8). Of these four stations, we only failed to collect crayfish at station 1142 in the two subsequent 1988 surveys, further suggesting that crayfish are widely distributed throughout the watershed.

Table 101.3.9. Total number of individual crayfish of each species collected during each of the three basin surveys during 1987 and 1988 in Champaign County.

Species	1987 Summer	1988 Spring	1988 Summer
Orconectes virilis	227	501	61
O. propinquis	34	35	22
O. immunis	1	1	-
Cambarus diogenes	15	6	-
Procambarus acutus	-	1	-

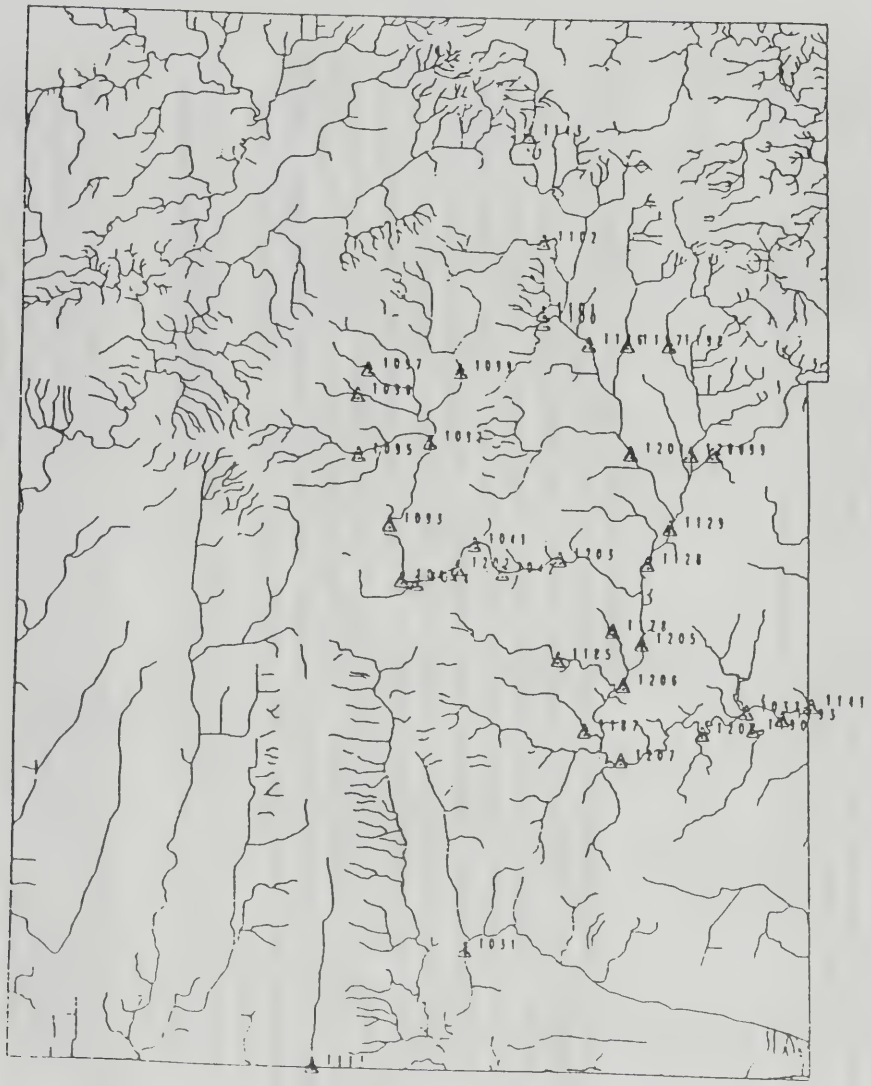


Figure 101.3.6. Distribution of *Orconectes virilis* in the Vermilion River drainage. Δ = station where species was found and ◊ = other stations.

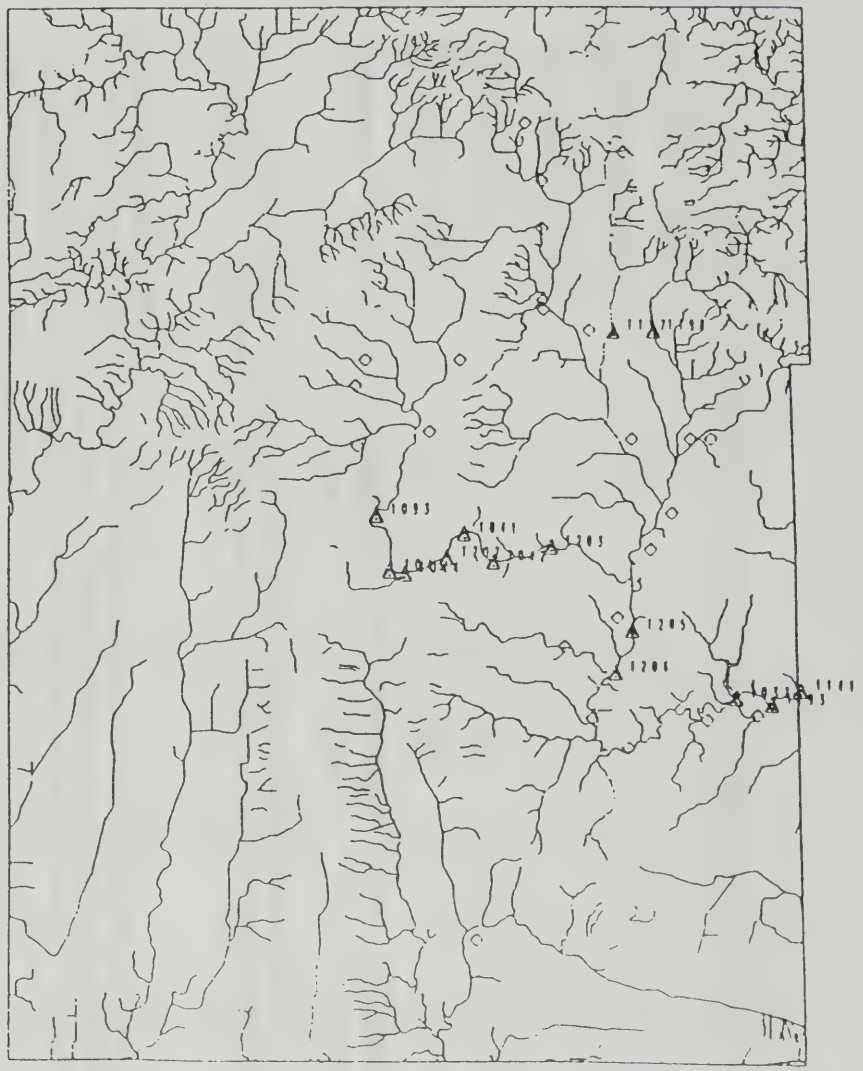


Figure 101.3.7. Distribution of *Orconectes propinquus* in the Vermilion River drainage. Δ = station where species was found and ◊ = other stations.

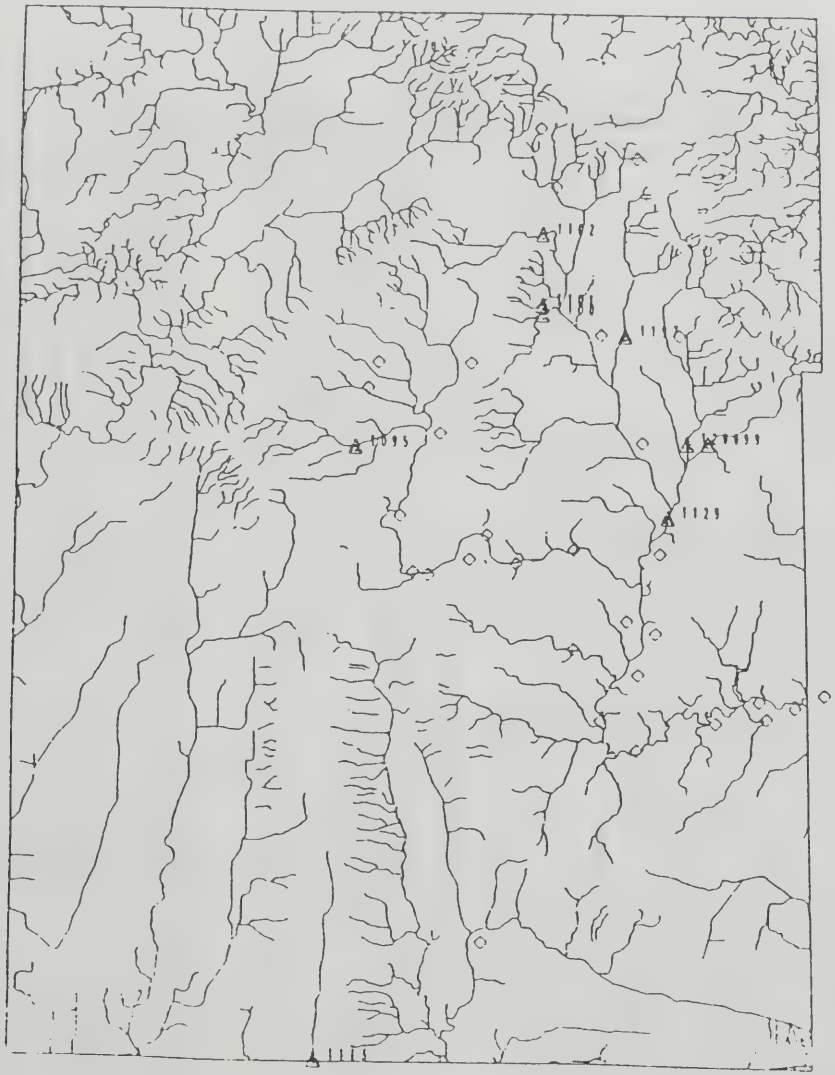


Figure 101.3.8. Distribution of *Cambarus diogenes* in the Vermilion River drainage. Δ = station where species was found and ◊ = other stations.

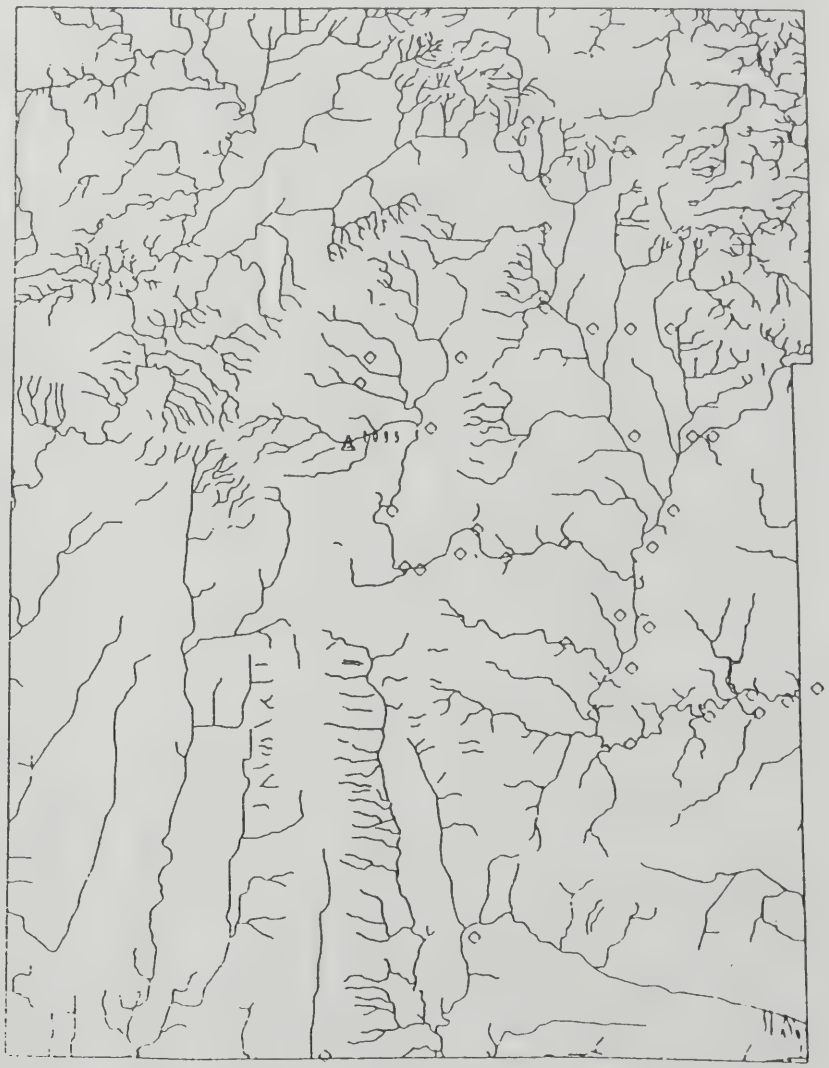


Figure 101.3.9. Distribution of *Procambarus acutus* in the Vermilion River drainage. Δ = station where species was found and ◊ = other stations.

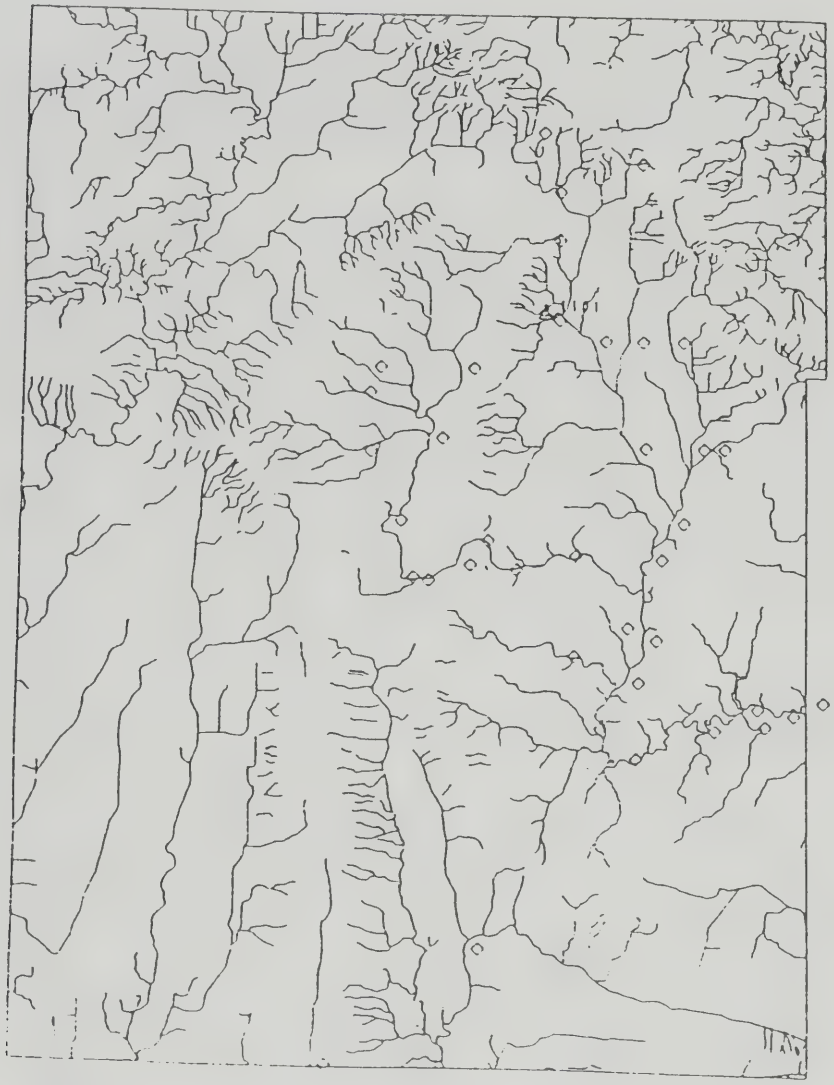


Figure 101.3.10. Distribution of *Orconectes immunis* in the Vermilion River drainage. Δ = station where species was found and ◊ = other stations.

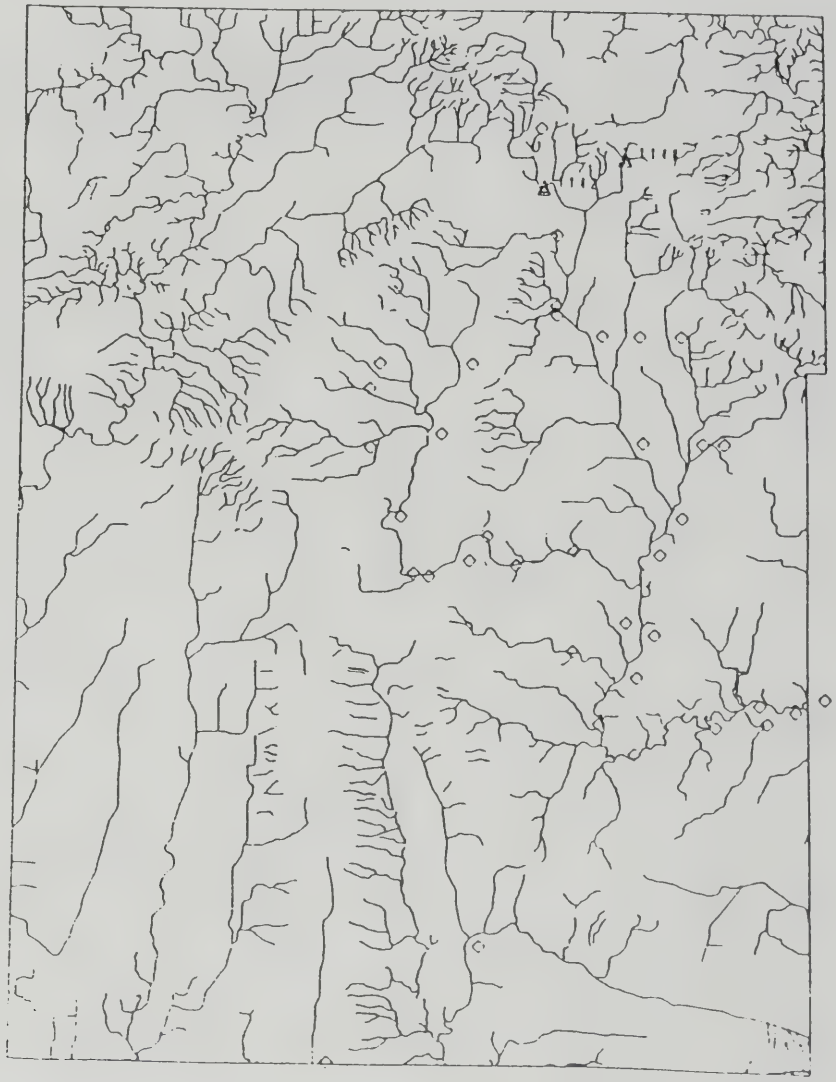


Figure 101.3.11. Stations with no crayfish in the Vermilion River drainage. Δ = station where no crayfish species was found and ◊ = other stations.

The species O. virilis, while most abundant (Table 101.3.9), also accounted for the broad based distribution of crayfish within the study area. O. virilis occurred at every station but two (Figure 101.3.6). Unlike O. virilis, O. propinquis was generally restricted to the Saline Branch, downstream of Urbana and to the larger and more downstream reaches of the Salt Fork River (Figure 101.3.7). These data provide evidence of a more restrictive or specialized habitat requirement for O. propinquis . Such a restriction of habitat use was Fig 101.3.6-7also suggested on the basis of the stomach content analysis of sportfish (see earlier section).

Despite the fact that the majority of stream reaches in Champaign County are dominated by shifting sand substrate with little in channel cover (see Job 101.2), crayfish densities were variable and at times, surprisingly high. In 1987, densities ranged from 0 crayfish/m^2 at stations 1142, 1205, 1207, and 1208 to a maximum density of 34 crayfish/m^2 at station 1190 (Table 101.3.8). High densities were also recorded in the spring of 1988 at stations 1102 and 1197 where densities of 40.4 and 37.6 crayfish/m^2, respectively were recorded.

Because the abundance of prey can limit the distribution of a predator, the successful management of sportfish populations requires that consideration of the available food supply be made. The importance of crayfish as a food item to several of the sportfish occurring in the drainage basin was demonstrated earlier (Figure 101.3.2). If crayfish are as important in the diet of smallmouth bass as stomach content analyses indicated, the variability in the density of crayfish across sampling stations may be one factor controlling the distribution of sportfish. In an attempt to identify the factors responsible for the limited distribution of smallmouth bass in the Vermilion River basin, we examined the relationship between the densities of smallmouth bass and crayfish (see below). A positive association between these two variables would suggest that smallmouth bass are limited in their distribution and abundance by food. The relationship of crayfish density to the density and distribution of smallmouth bass and other sportfish are presented along with the relationship of these sportfish to other physical, chemical, riparian land use, and biological parameters in a subsequent section of this report.

Morphometric Relationships

As expected, the relationships between the total lengths, carapace lengths, and chela lengths and dry weights of crayfish were highly significant and positive (Figure 101.3.12 and Table 101.3.10). Use of all individuals within a species from across these collections should provide models that are more generally applicable across the region because of the obvious difference of sampling stations and the range of environmental conditions that existed during the study. All relationships explained greater than 93% of the variation in dry weights among the three species (Table 101.3.10). There was only minimal differences between the quality of each of the models across morphometric parameters. The poorest relationships were those associated with O. virilis, but even these explained 93-94% of the variance in dry weights of individual crayfish. The models for O. virilis are slightly different from similar models (equations 1 and 2 in previous fish stomach analysis section) for this species only because of sample size differences. Those in Table 101.3.10 included data in equations 1 and 2 as well as data collected during both 1988 surveys. For these reasons, the models in Table 101.3.10 are felt to be applicable across a wider geographic range.

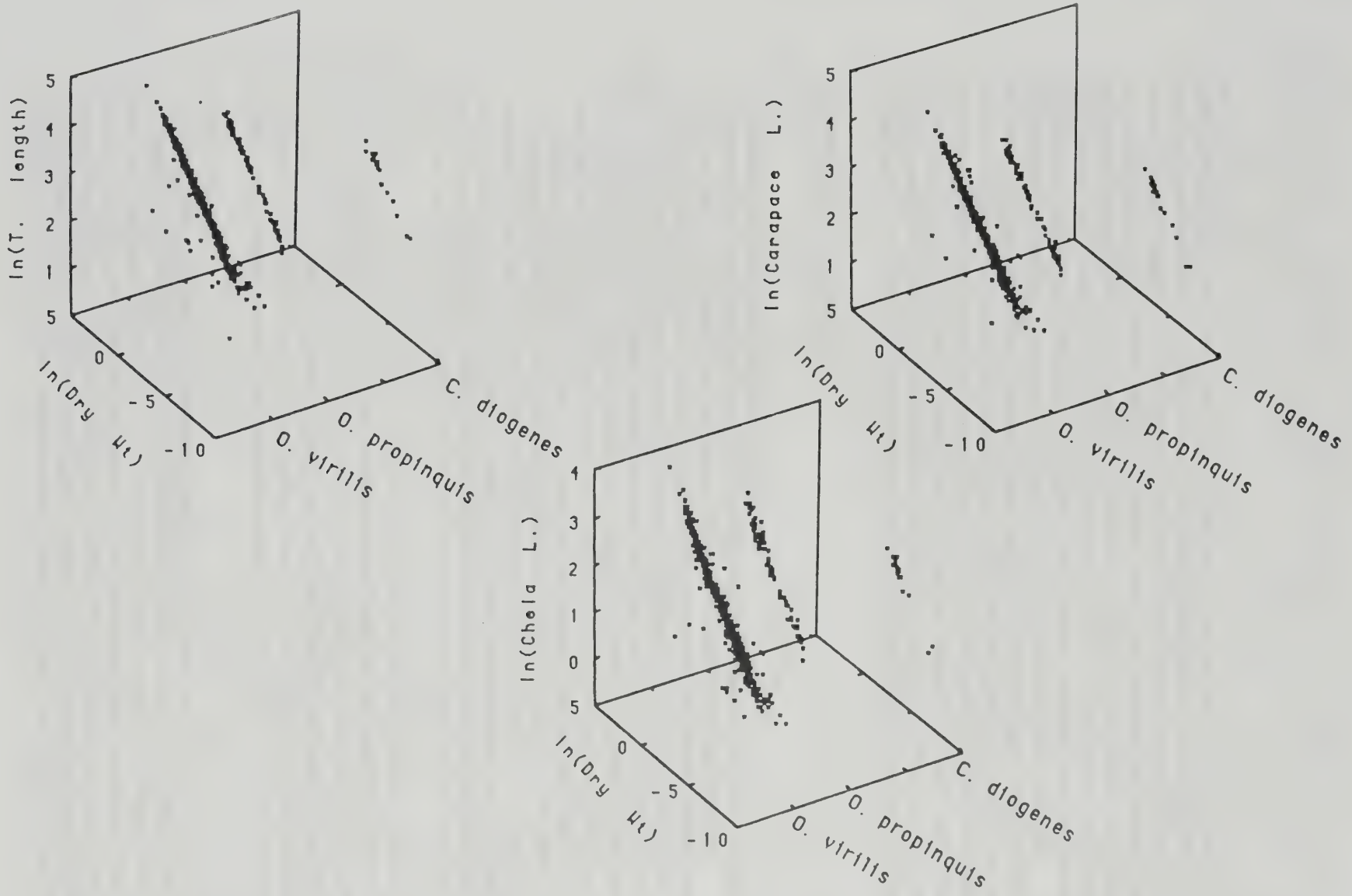


Figure 101.3.12. Relationship between the natural logarithm of chela length (mm), carapace length (mm), and total length and the ln dry weight for the three most common crayfish species in the streams of Champaign County.

Table 101.3.10. Relationship between the natural logarithm of total length, carapace length, and chela length (mm) and log (dry weight) of O. virilis, O. propinquis, and C. diogenes in the Vermilion River basin and associated statistics. S.E. is the standard error of the model estimate. DW = log (dry weight)(g), Chela = Chela length (mm), TL = Total length (mm), and CL = Carapace length (mm).

Species	Model	P	R^2	S.E.
O. virilis				
	DW = -13.29 + 3.28 ln(TL)	0.000	0.93	0.71
	DW = -11.75 + 3.53 ln(CL)	0.000	0.94	0.65
	DW = - 7.72 + 2.73 ln(Chela)	0.000	0.93	0.74
O.propinquis				
	DW = -13.43 + 3.42 ln(TL)	0.000	0.99	0.25
	DW = -11.41 + 3.55 ln(CL)	0.000	0.99	0.30
	DW = - 8.15 + 2.83 ln(Chela)	0.000	0.98	0.42
C. diogenes				
	DW = -13.27 + 3.31 ln(TL)	0.000	0.98	0.29
	DW = -11.09 + 3.34 ln(CL)	0.000	0.99	0.21
	DW = - 8.19 + 2.89 ln(Chela)	0.000	0.97	0.32

BENTHIC MACROINVERTEBRATES

METHODS

Benthic samples were collected at 30 stations in the Vermilion River during autumn 1987. These stations correspond to 25 of the stations sampled for detailed crayfish analysis (see Osborne et al. 1988). Six samples were collected from each station using one or a combination of three sampling devices [a plexiglass core sampler (0.00196 m^2) in shallow sand reaches, a larger core sampler (0.00352 m^2) for deep sand/clay reaches, and/or a Surber sampler (0.093 m^2) in shallow riffle zones]. A station was sampled with a single sampling device or a combination of devices depending on the proportion of each habitat type in the stream reach. When the small core sampler was used, two cores were combined in a single sample. Samples were preserved in 7% formalin and returned to the laboratory for processing.

In the laboratory, samples were sorted using a dissecting microscope at 10x magnification. Invertebrates were identified to the lowest practical taxon depending on the group. Invertebrates were divided into three size classes (<5, 5-10, >10 mm) for each order. Dry weights were determined at the ordinal level for each size class by drying the samples at 90°C for 24 h and weighing them on a CAHN C-31 microbalance to the nearest microgram.

Organic material from each benthic sample was dried at 90°C for 24 h, weighed on a Mettler H balance, ashed at 550°C for 1 h, and reweighed as an index of the percent organic matter at each station.

RESULTS

The taxa of benthic macroinvertebrates collected during the study and their associated phylogeny are presented in Table 101.3.11. In 1987, the mean taxa richness of benthic

Table 101.3.11. Species list of macroinvertebrates collected within the Vermillion River basin at the Fishes of Champaign County sampling stations in 1987 through 1989 and the associated taxa code. (* = species collected from fish stomach analysis.)

Code	Order	Family	Genus	species
4	Turbellaria			
5	Oligochaeta			
6*	Diplopoda			
7	Nematoda			
8	Coelenterata			
90*	Hymenoptera			
92*	Hymenoptera	Formicidae		
100	Ephemeroptera			
101	Ephemeroptera	Siphlonuridae		
102	Ephemeroptera	Siphlonuridae	Isonychia	
107	Ephemeroptera	Siphlonuridae	Ameletus	
110	Ephemeroptera	Baetidae		
111	Ephemeroptera	Baetidae	Baetis	
112	Ephemeroptera	Baetidae	Baetis	intercalaris
113	Ephemeroptera	Baetidae	Baetis	flavistriga
114	Ephemeroptera	Baetidae	Baetis	hageni
115	Ephemeroptera	Baetidae	Baetis	pygmaeus
125	Ephemeroptera	Baetidae	Callibaetis	
130	Ephemeroptera	Baetidae	Centroptilon	
135	Ephemeroptera	Baetidae	Cloeon	
140	Ephemeroptera	Baetidae	Paracloedes	
141	Ephemeroptera	Baetidae	Paracloedes	prob. minutus
143	Ephemeroptera	Baetidae	Pseudocloeon	
144	Ephemeroptera	Baetidae	Pseudocloeon	parvulum
145	Ephemeroptera	Heptageniidae		
147	Ephemeroptera	Heptageniidae	Heptagenia	
158	Ephemeroptera	Heptageniidae	Leucocrouta	hebe
167	Ephemeroptera	Heptageniidae	Stenacron	
168	Ephemeroptera	Heptageniidae	Stenacron	interpunctatum
169	Ephemeroptera	Heptageniidae	Stenacron	minnetonka
170	Ephemeroptera	Heptageniidae	Stenacron	candidum
175	Ephemeroptera	Heptageniidae	Stenonema	
176	Ephemeroptera	Heptageniidae	Stenonema	integrum
177	Ephemeroptera	Heptageniidae	Stenonema	bipunctatum
178	Ephemeroptera	Heptageniidae	Stenonema	pelchellum
179	Ephemeroptera	Heptageniidae	Stenonema	tripunctatum
180	Ephemeroptera	Heptageniidae	Stenonema	ares
181	Ephemeroptera	Heptageniidae	Stenonema	femoratum
182	Ephemeroptera	Heptageniidae	Stenonema	quinquespinum
183	Ephemeroptera	Heptageniidae	Stenonema	luteum
192*	Ephemeroptera	Ephemerellidae	Ephemerella	inermis
221	Ephemeroptera	Tricorythithidae	Tricorythodes	
231	Ephemeroptera	Caenidae	Brachycerus	
235	Ephemeroptera	Caenidae	Caenis	
246	Ephemeroptera	Baetiscidae	Baetisca	
251	Ephemeroptera	Potamanthidae	Potamanthus	
252	Ephemeroptera	Potamanthidae	Potamanthus	myops
260	Ephemeroptera	Ephemeridae		
262	Ephemeroptera	Ephemeridae	Ephemera	simulans

Table 101.3.11. continued.

Code	Order	Family	Genus	species
270	Ephemeroptera	Ephemeridae	Hexagenia	
271	Ephemeroptera	Ephemeridae	Hexagenia	limbata
272	Ephemeroptera	Ephemeridae	Hexagenia	bilineata
273	Ephemeroptera	Ephemeridae	Hexagenia	munda
274	Ephemeroptera	Ephemeridae	Hexagenia	rigida
300	Diptera			
301	Diptera	Chironomidae		
303	Diptera	Ceratopogonidae		
302	Diptera	Ceratopogonidae	Palpomyia complex	
305	Diptera	Ceratopogonidae	Alluadomyia	needhami
306	Diptera	Ceratopogonidae	Stilobezzia	
307	Diptera	Ceratopogonidae	Stilobezzia	atrichopogon
312	Diptera	Ceratopogonidae	Stilobezzia	bulla
316	Diptera	Ceratopogonidae	Culicoides	
308	Diptera	Empididae		
309	Diptera	Empididae	Hemerodromia	
311	Diptera	Empididae	Clinocera	
314	Diptera	Canaceidae		
315	Diptera	Rhagionidae		
317	Diptera	Culicidae		
319	Diptera	Scathophagidae	Cordilura	
320	Diptera	Chaoboridae		
321	Diptera	Chaoboridae	Chaoborus	
322	Diptera	Chaoboridae	Chaoborus	punctipennis
323	Diptera	Dilochopodidae		
325	Diptera	Simuliidae		
326	Diptera	Simuliidae	Prosimulium	
327	Diptera	Simuliidae	Prosimulium	simulium
330	Diptera	Tipulidae		
331	Diptera	Tipulidae	Limnophila	
332	Diptera	Tipulidae	Erioptera	
333	Diptera	Tipulidae	Pilaria	
334	Diptera	Tipulidae	Tipula	
343	Diptera	Tipulidae	Gonomyia	
336*	Diptera	Tipulidae	Antocha	
337	Diptera	Tipulidae	Cryptolabis	
338	Diptera	Tipulidae	Ormosia	
344	Diptera	Tipulidae	Helius	
340	Diptera	Tabanindae		
341	Diptera	Tabanindae	Chrysops	
342	Diptera	Muscidae		
345	Diptera	Ephydridae		
346	Diptera	Ephydridae	Brachydeutera	
348	Diptera	Psychodidae		
349	Diptera	Psychodidae	Psychoda	
350	Odonata			
351	Odonata	Coenagrionidae		
352	Odonata	Coenagrionidae	Argia	
354	Odonata	Coenagrionidae	Chromagrion	
356	Odonata	Coenagrionidae	Hespiragrion	
365	Odonata	Libellulidae		

Table 101.3.11. continued.

Code	Order	Family	Genus	species
366	Odonata	Libellulidae	Sympetrum	
367	Odonata	Libellulidae	Plathemis	
368	Odonata	Libellulidae	Orthemis	
370	Odonata	Gomphidae	.	
371	Odonata	Gomphidae	Gomphus	
375	Odonata	Gomphidae	Progomphus	
376	Odonata	Gomphidae	Erpetogomphus	
378	Odonata	Gomphidae	Dromogomphus	spinosus
381	Odonata	Macromiidae	Macromia	
385*	Odonata	Cordulidae		
386	Odonata	Cordulidae	Somatochlora	
388	Odonata	Cordulidae	Neurocordulia	virginiensis
391	Odonata	Calopterygidae	Hetaerina	
400	Coleoptera			
399*	Terest. coleoptera			
401	Coleoptera	Elmidae		
402	Coleoptera	Elmidae	Dubiraphia	
403	Coleoptera	Elmidae	Dubiraphia	vittata
404	Coleoptera	Elmidae	Dubiraphia	quadrinotata
406	Coleoptera	Elmidae	Stenelmis	
405	Coleoptera	Elmidae	Stenelmis	crenata
407	Coleoptera	Elmidae	Stenelmis	sexlineata
408	Coleoptera	Elmidae	Stenelmis	vittipennis
409	Coleoptera	Elmidae	Macronychus	
410	Coleoptera	Elmidae	Macronychus	glabratus
411	Coleoptera	Ditiscidae		
412	Coleoptera	Ditiscidae	Hyperius	
413	Coleoptera	Ditiscidae	Oreodytes	
417	Coleoptera	Dryopidae	Helichus	lithophilus
420	Coleoptera	Hydrophilidae		
421	Coleoptera	Hydrophilidae	Berosus	
422	Coleoptera	Hydrophilidae	Enochrus	
423	Coleoptera	Hydrophilidae	Laccobius	
425	Coleoptera	Hydrophilidae	Hydrochus	
426	Coleoptera	Hydrophilidae	Hydrobius	
431	Coleoptera	Haliplidae	Haliplus	
433	Coleoptera	Haliplidae	Peltodytes	
440*	Coleoptera	Helodidae		
441	Coleoptera	Helodidae	Cyphon	
445*	Coleoptera	Histeridae		
447	Coleoptera	Curculionidae		
449	Coleoptera	Chrysomelidae	Donacia	
446	Coleoptera	Chrysomelidae	Agasicles	
451	Trichoptera	Hydroptilidae		
452	Trichoptera	Hydroptilidae	Hydroptila	
453	Trichoptera	Hydroptilidae	Hydroptila	ajax
454	Trichoptera	Hydroptilidae	Hydroptila	angusta
455	Trichoptera	Hydroptilidae	Neotrichia	
456	Trichoptera	Hydroptilidae	Hydroptila	spatulata
457	Trichoptera	Hydroptilidae	Hydroptila	armata
458	Trichoptera	Hydroptilidae	Hydroptila	waubesiana

Table 101.3.11. continued.

Code	Order	Family	Genus	species
461	Trichoptera	Hydroptilidae	Agraylea	multipunctata
465*	Trichoptera	Hydroptilidae	Orthotrichia	
466	Trichoptera	Hydroptilidae	Orthotrichia	tarsalis
472	Trichoptera	Rhyacophilidae	Rhyacophila	lobifera
473	Trichoptera	Rhyacophilidae	Rhyacophila	fuscula
500	Trichoptera	Hydropsychidae		
501	Trichoptera	Hydropsychidae		
502	Trichoptera	Hydropsychidae	Hydropsyche	
503	Trichoptera	Hydropsychidae	Hydropsyche	simulans
504	Trichoptera	Hydropsychidae	Hydropsyche	betteni
505	Trichoptera	Hydropsychidae	Hydropsyche	frisoni
506	Trichoptera	Hydropsychidae	Hydropsyche	chelonis
507	Trichoptera	Hydropsychidae	Hydropsyche	sparna
508	Trichoptera	Hydropsychidae	Hydropsyche	slossone
509*	Trichoptera	Hydropsychidae	Hydropsyche	bifida group
515	Trichoptera	Hydropsychidae	Cheumatopsyche	
531	Trichoptera	Lymnephiidae	Pycnopsyche	
541	Trichoptera	Psychomidae	Psychomiya	
582	Trichoptera	Philopotomidae	Chimarra	obscura
600	Trichoptera	Leptoceridae		
601	Trichoptera	Leptoceridae	Oecetis	
602	Trichoptera	Leptoceridae	Oecetis	inconspicua
606	Trichoptera	Leptoceridae	Trigenodes	tarda
611	Trichoptera	Leptoceridae	Nectopsyche	diarina
623*	Trichoptera	Helicopsychidae	Helicopsyche	
624	Trichoptera	Helicopsychidae	Helicopsyche	borealis
626	Hemiptera	Corixidae		
627	Hemiptera	Corixidae	Trichocorixa	
628	Hemiptera	Corixidae	Trichocorixa	calva
629	Hemiptera	Corixidae	Trichocorixa	kanza
630	Hemiptera	Corixidae	Trichocorixa	reticulata
631	Hemiptera	Corixidae	Trichocorixa	naias
636	Hemiptera	Corixidae	Palmacorixa	buenoi
640	Hemiptera	Corixidae	Dasycorixa	
650	Hemiptera	Gerridae		
665	Hemiptera	Veliidae		
671*	Hemiptera	Nepidae	Nepa	
675	Plecoptera			
678	Plecoptera	Taeniopterygidae	Taeniopteryx	burski
687	Plecoptera	Perlidae	Perlesta	placida
690	Plecoptera	Perlodidae	Isoperla	clio
693	Plecoptera	Capniidae	Allocapnia	vivipara
720	Colembola			
721	Colembola	Hypogastruridae		
723	Colembola	Isotomidae	Semicera	
724	Colembola	Entomobryidae		
725	Lepidoptera			
726	Lepidoptera	Pyralidae		
727	Lepidoptera	Pyralidae	Petrophila	
728	Lepidoptera	Pyralidae	Petrophila	
735*	Lepidoptera	Noctuiidae		

Table 101.3.11. continued.

Code	Order	Family	Genus	species
741	Lepidoptera	Tortricidae	Archips	
750*	Megaloptera			
752	Megaloptera	Sialidae	Sialis	
760*	Megaloptera	Corydalidae		
761*	Megaloptera	Corydalidae	Corydallus	
790*	Orthopera			
791*	Orthopera	Locustidae		
795	Acarina			
801*	Decapoda	Cambaridae		
802*	Decapoda	Cambaridae	Orconectes	
804	Decapoda	Cambaridae	Orconectes	propinquus
805	Decapoda	Cambaridae	Orconectes	virilis
815*	Decapoda	Cambaridae	Cambarus	tenebrosus
825	Isopoda			
827	Isopoda	Asellidae	Asellus	
840	Isopoda	Asellidae	Lirceus	
868	Amphipoda	Hyallelidae	Halella	azteca
870	Amphipoda	Gammaridae	Gammarus	
875	Hirudinea			
877	Hirudinea	Glossiphoniidae		
878	Hirudinea	Glossiphoniidae	Placobdella	
885	Hirudinea	Erpobdellidae		
886	Hirudinea	Erpobdellidae	Dina	
887	Hirudinea	Erpobdellidae	Dina	microstoma
889	Hirudinea	Erpobdellidae	Erpobdella	punctata
890	Hirudinea	Arhynchobdellidae		
900	Gastropoda			
901	Gastropoda	Ancylidae		
902	Gastropoda	Ancylidae	Ferrissia	
903	Gastropoda	Ancylidae	Ferrissia	rivularis
906	Gastropoda	Hydrobiidae		
910	Gastropoda	Physidae		
911	Gastropoda	Physidae	Physa	
913	Gastropoda	Physidae	Physella	
915	Gastropoda	Lymnaeidae		
917	Gastropoda	Lymnaeidae	Pseudosuccinea	columella
920	Gastropoda	Lymnaeidae	Fossaria	
925	Gastropoda	Planorbidae		
927	Gastropoda	Planorbidae	Menetus	dilatus
940	Gastropoda	Pleuroceridae		
941*	Gastropoda	Pleuroceridae	Pleurocera	
950	Bivalvia			
952	Bivalvia	Corbiculidae	Corbicula	
953	Bivalvia	Corbiculidae	Corbicula	fluminea
954	Bivalvia	Sphaeriidae		
956	Bivalvia	Sphaeriidae	Shpaerium	
957	Bivalvia	Sphaeriidae	Shpaerium	simile
958	Bivalvia	Sphaeriidae	Shpaerium	transversum
965	Bivalvia	Sphaeriidae	Pisidium	
966	Bivalvia	Sphaeriidae	Pisidium	amnicum
967	Bivalvia	Sphaeriidae	Pisidium	falax

Table 101.3.11. continued.

Code	Order	Family	Genus	species
975	Bivalvia	Unionidae		
977	Bivalvia	Unionidae	Lamsis	fasciola
981	Bivalvia	Unionidae	Toxolasma	parvus
985	Bivalvia	Unionidae	Lasmigona	complanata

macroinvertebrates, excluding crayfish, was 14 ± 10 taxa (Table 101.3.12). Such a taxa richness of benthic invertebrates is somewhat low, but it is important to note that because of time and budgetary constraints, chironomids and other difficult to identify taxa were only identified to the familial level. Because of the similarity in size of these organisms and their widespread occurrence, such a taxonomic level should be sufficient for most ecological questions concerning fish communities. Thus, the taxa richness values should be interpreted with caution if comparisons to other data sets are to be made. The limited occurrence of taxa characteristic of "pristine" conditions , or hard-bottom substrata, such as many of the mayfly, stonefly, and caddisfly taxa reflects the unstable and sandy or silty nature of the stream bottoms in this region. On average, the majority of the biomass of benthic macroinvertebrates was composed of large (>10 mm length) individuals (Table 101.3.12). Such was not the case at all stations, however, as indicated by the absence of medium sized and large size invertebrates at some stations (Table 101.3.12). Because we earlier reported a distinct relationship between the size of prey ingested and the size of

Table 101.3.12. The mean, standard deviation, and range in macroinvertebrate (excluding crayfish) densities, species richness, and biomass of the different size categories of invertebrates and the number and biomass of crayfish and the percent organic matter of sediments at selected 1987 sampling stations in the Vermilion River basin.

Parameter	Mean	S.D.	Minimum	Maximum	N
Species Richness	14.0	9.9	2.0	45.0	30
No. Invertebrates/m^2	16,066.3	19,780.9	284.0	82,993.0	30
Total Biomass of Invertebrates (mg/m^2)	7,227.7	18,387.4	17.5	93,481.0	29
Biomass of Small Invertebrates (mg/m^2)	594.4	913.5	17.5	4,126.8	29
Biomass of Medium Invertebrates (mg/m^2)	613.9	1,206.3	0.0	5,119.6	29
Biomass of Large Invertebrates (mg/m^2)	6,019.4	18,302.6	0.0	92,913.9	29
Density of Crayfish/m^2	4.1	6.8	0.0	34.0	33
Crayfish biomass (mg/m^2)	2,050.0	2,570.0	0.0	12,330.0	33
Percent (by Weight) Organic Matter	2.45	3.30	0.74	17.30	29

sportfish predator, these differences in the abundance of different prey sizes may contribute to the differential densities and distribution of sportfish across sampling stations.

Our earlier studies indicated that crayfish comprised a substantial proportion of the diet of the smallmouth bass and rock bass examined. These data indicate that on average, crayfish comprise 22% of the total invertebrate biomass (crayfish + other macroinvertebrates) in streams in the Vermilion basin during the summer months.

The proportion of organic matter in the sediments of streams was fairly low on average (2.45% ± 3.3%) although a maximum value of 17.3% was recorded at one station. The low proportion of organic matter in the stream sediments is likely a function of the limited capacity of the stream systems in the agricultural midwest to retain organic matter and, of the limited input of coarse particulate organic matter (CPOM) such as leaves and twigs. The limited retention capacity is a function of the unstable substrata and relatively straight stream channels while the limited input of CPOM is a function of the lack of riparian forests and vegetation. These factors contribute to the autotrophic nature of the majority of stream reaches in watershed dominated by row-crop agriculture (Wiley et al. 1990).

FACTORS INFLUENCING THE ABUNDANCE OF SPORTFISH

METHODS

In an attempt to identify factors responsible for the limited distribution and abundance of sportfish in the Vermilion River basin we compared the densities and biomass of all individuals, and those less than 100 mm (YOY) and greater than or equal to 100 mm (large) in total length (TL) for black basses, rock bass, channel catfish, and grass pickerel at 37 sampling stations to a set of uncorrelated environmental parameters using Spearman Rank correlation analysis (Wilkinson 1989). The < 100 mm group (YOY) correspond closely to young-of-the-year black bass species and includes all or most of the YOY of the other sportfish species. Because of the limited number of individuals in each of the black bass species (i.e., smallmouth bass, spotted bass, and largemouth bass) in the 1987 collections, we pooled the data on the distribution and densities of these species to generate the black bass category. A Spearman Rank analysis was selected over parametric procedures because of the large number of stations where target sportfish species were absent. In essence we were unable to meet the assumptions of the parametric procedure and resorted to the non-parametric rank procedure. The environmental parameters measured consisted of three riparian land use parameters, six physical habitat parameters, four water chemistry parameters, and five biological parameters (Table 101.3.13). The total bank undercut parameter was generated by averaging the amount of undercut bank on the left and right banks of each sampling reach. The significance of the relationships between the log transformed environmental variables were determined using Bonferroni's procedure.

In addition to the uncorrelated environmental parameters discussed previously, we also included the biomass of prey fish less than 80 mm in total length. This was done because of the importance of fish within this size range in the diets of many of the sportfish (see fish stomach analysis section). Differences in sample size were due to non-concordance in sampling the different parameters in 1987. These same parameters were measured in 1988, but to assess the influence of the drought. Because of the potential impact of drought conditions on the distribution of the sportfish, which could confound the interpretation of these environmental parameters during a typical year, we excluded the 1988 data from this analysis.

Table 101.3.13. Environmental parameters with respect to general environmental category compared to sportfish densities in 1987.

Category	Parameter	No. Stations Measured
Riparian Landuse	Percent Right Bank Soybean	26
	Percent Right Bank Corn	26
	Percent Right Bank Buffer Crop	26
Physical Habitat	Total Shading	33
	Total Bank Undercut	33
	Percent Channel Vegetative Cover	33
	Coefficient of Variation in Velocity	33
	Mean Depth	33
	Percent Organic Matter of Sediment	29
Chemical Habitat	Specific Conductance	32
	Turbidity	32
	Soluble Reactive Phosphorus (SRP)	32
	Ammonia-N (NH_3-N)	32
Biological	Density of Macroinvertebrates (excluding crayfish)	30
	Biomass (mg/m^2) of Crayfish	33
	Total Biomass Invertebrates (mg/m^2)	29
	Biomass (mg/m^2) of Medium Sized Invertebrates	29
	Biomass (mg/m^2) of prey fish (< 80 mm)	37

RESULTS

Total densities of black bass were positively correlated with mean depth and amount of undercut bank and negatively correlated with ammonia concentration and the mean biomass of prey fish (Table 101.3.14). Mean depth and biomass of prey fish were also strongly associated with large and yoy black bass. The negative correlation between black bass distribution and the abundance of prey appears paradoxical. However, the negative association between the sportfish distribution and abundance and the density of prey fish has a rational explanation, it could be due to the direct influence of black bass predation on prey fish densities and/or an avoidance response of prey to the presence of predatory black bass.

Sources of high concentrations of ammonia-N in the streams of east-central Illinois can be attributed to its use on agricultural fields, or to its presence in municipal sewage effluents. Because ammonia in point source effluents has generally declined following installation of secondary treatment processes in most urban facilities, its use in agriculture is the most likely source for the elevated ammonia levels. The negative association with ammonia-N (Table 101.3.14) would thus indicate that diffuse sources of ammonia-N are limiting the the distribution and abundance of black bass populations in central Illinois.

Table 101.3.14. Results of Spearman Rank Correlation analyses between Large (≥ 100 mm TL), young of year, YOY (< 100 mm TL), and total black basses (smallmouth, largemouth, and spotted basses) densities and independent environmental parameters. Values in parentheses are the number of paired station samples.

Environmental Parameter	Large	YOY	Total
Crayfish Biomass (wt./m^2)	-0.152 (29)	-0.296 (29)	-0.296 (29)
Invertebrate Density (Ind/m^2)	-0.340 (29)	-0.202 (29)	-0.258 (29)
Medium Size Invertebrate Biomass (wt./m^2)	0.097 (28)	-0.054 (28)	-0.024 (28)
Ammonia	-0.222 (32)	-0.317 (32)	-0.319 (32)
Soluble Reactive Phosphorus	0.116 (32)	0.227 (32)	0.196 (32)
Turbidity	0.441 (32)	0.153 (32)	0.240 (32)
Specific Conductance	0.105 (32)	0.137 (32)	0.092 (32)
Mean Depth	0.329 (34)	0.429 (34)	0.440 (34)
C.V. Velocity	-0.202 (32)	-0.404 (32)	-0.300 (32)
Channel Vegetation Cover	0.048 (32)	0.010 (32)	-0.011 (32)
Total Undercut	0.298 (32)	0.203 (32)	0.334 (32)
Total Shading	0.170 (32)	-0.021 (32)	0.063 (32)
Percent RB Buffer Crop	-0.161 (28)	-0.161 (28)	-0.197 (28)
Percent RB Corn	-0.216 (28)	0.043 (28)	-0.023 (28)
Percent RB Soybean	-0.216 (28)	-0.216 (28)	-0.266 (28)
Total Invertebrate Biomass/m^2	-0.026 (28)	0.003 (28)	-0.032 (28)
Percent Organic Matter	0.092 (26)	-0.021 (26)	-0.028 (26)
Prey Fish Biomass	-0.368 (33)	-0.440 (33)	-0.419 (33)

The positive association between the distribution and abundance (Table 101.3.14) and biomass (Table 101.3.16) of black bass and mean channel depth and the amount of bank undercut reflects the importance of pools and within channel habitat cover to black bass populations. These results provide insights into channel modifications and practices that would be required in restoration programs to broaden the distribution of black bass in Champaign County. Further, these results serve to characterize the negative effects that channelization and present channel maintenance practices have on the distribution and abundance of sportfish.

The preceding analysis utilized data from all 32 stations in which detailed habitat data and fish population data were collected in 1987. We also conducted a similar analysis using data from only those stations where black bass were collected to better identify environmental factors influencing density rather than distribution. The results of this analysis indicate that stream black bass populations can be increased by increasing channel vegetative cover (Table 101.3.15). The negative relationship with total shading is opposite of what was initially expected but, is probably associated with the fact that many of the channelized stream reaches also had steep, incised banks that provided substantial shading. The fact that turbidity increased with stream size, and larger streams generally had more complex habitats explains the positive association between adult black bass density and turbidity (Table 101.3.15) . Thus, the positive relationship with turbidity should not be interpreted as suggesting that increased sediment loading (generally associated with higher turbidity) is beneficial to black bass populations; rather, it reflects the fact that turbidity is highly correlated with other environmental parameters previously removed from the analysis.

Factors influencing the biomass of black bass were less clear cut than those for density, and varied with ontogeny (Table 101.3.17). The negative association between the biomass of large fish and the proportion of riparian areas planted in corn again reflects the adverse influence of agricultural landuse on sportfish populations. Similarly, the positive association with turbidity and the proportion of organic material in the sediments again reflects the benefits associated with larger streams. The density of young black bass were positively associated with channel vegetative cover, the biomass of other prey fish, and homogeneous and relatively slow velocity conditions (Table 101.3.17). Thus, factors influencing the biomass of large and young of year (YOY) black bass differ, suggesting that management programs designed to increase black bass populations must first identify the life stage for which environmental conditions are limiting.

The density of crayfish populations was negatively correlated with the density and abundance of rock bass (Table 101.3.18). Our earlier analyses revealed that crayfish comprised a significant component of the diet of rock bass. The negative association between crayfish biomass and rock bass populations is similar to earlier reported results with black bass (Table 101.3.14 - 16) and likely reflects the impact of rock bass predation on crayfish densities and/or behavior. The positive relationship with turbidity and the negative association with variability in stream velocity (Table 101.3.18) is characteristic of pool habitats located in the larger streams within the study area. Thus, these results indicate that increasing pool habitats will likely have a positive influence on both black bass and rock bass populations.

Unquestionably, the most consistent parameter associated with the distribution and abundance of channel catfish in Champaign County streams was the degree of undercut banks (Table 101.3.19). Similar to other sportfish, these results also indicate a negative

Table 101.3.15. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL), young of year, YOY (< 100 mm TL), and total black basses (smallmouth, largemouth, and spotted basses) densities and independent environmental parameters using only the stations where black basses were present. Values in parentheses are the number of paired station samples.

Environmental Parameter	Large	YOY	Total
Crayfish Biomass (wt./m^2)	0.211 (4)	0.200 (4)	0.200 (4)
Invertebrate Density (Ind/m^2)	-0.287 (8)	0.048 (8)	0.167 (8)
Medium Size Invertebrate Biomass (wt./m^2)	0.263 (8)	-0.096 (8)	-0.167 (8)
Ammonia	0.036 (7)	-0.486 (7)	-0.432 (7)
Soluble Reactive Phosphorus	-0.345 (7)	0.321 (7)	-0.036 (7)
Turbidity	0.847 (7)	-0.091 (7)	0.179 (7)
Specific Conductance	0.573 (7)	0.450 (7)	0.739 (7)
Mean Depth	-0.277 (9)	0.101 (9)	-0.100 (9)
C.V. Velocity	-0.491 (7)	-0.330 (7)	-0.559 (7)
Channel Vegetation Cover	0.618 (7)	0.520 (7)	0.612 (7)
Total Undercut	-0.191 (7)	-0.073 (7)	-0.072 (7)
Total Shading	-0.180 (7)	-0.473 (7)	-0.679 (7)
Percent RB Buffer Crop	. (7)	. (7)	. (7)
Percent RB Corn	-0.520 (7)	0.412 (7)	0.408 (7)
Percent RB Soybean	. (7)	. (7)	. (7)
Total Invertebrate Biomass/m^2	-0.036 (8)	0.169 (8)	0.048 (8)
Percent Organic Matter	0.714 (6)	0.261 (6)	0.371 (6)
Prey Fish Biomass	0.261 (9)	-0.368 (9)	-0.233 (9)

Table 101.3.16. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL) young of year, YOY (< 100 mm TL), and total black basses (smallmouth, largemouth, and spotted basses) biomasses and independent environmental parameters. Values in parentheses are the number of paired station samples.

Environmental Parameter	Large	YOY	Total
Crayfish Biomass (wt./m^2)	-0.152 (29)	-0.307 (29)	-0.292 (29)
Invertebrate Density (Ind/m^2)	-0.354 (29)	-0.194 (29)	-0.307 (29)
Medium Size Invertebrate Biomass (wt./m^2)	0.119 (28)	-0.072 (28)	0.035 (28)
Ammonia	-0.231 (32)	-0.311 (32)	-0.308 (32)
Soluble Reactive Phosphorus	0.131 (32)	0.210 (32)	0.195 (32)
Turbidity	0.436 (32)	0.169 (32)	0.277 (32)
Specific Conductance	0.090 (32)	0.163 (32)	0.069 (32)
Mean Depth	0.342 (34)	0.419 (34)	0.434 (34)
C.V. Velocity	-0.187 (32)	-0.415 (32)	-0.270 (32)
Channel Vegetation Cover	0.035 (32)	0.016 (32)	-0.022 (32)
Total Undercut	0.301 (32)	0.271 (32)	0.352 (32)
Total Shading	0.173 (32)	-0.034 (32)	0.099 (32)
Percent RB Buffer Crop	-0.161 (28)	-0.161 (28)	-0.197 (28)
Percent RB Corn	-0.216 (28)	0.043 (28)	-0.083 (28)
Percent RB Soybean	-0.216 (28)	-0.216 (28)	-0.266 (28)
Total Invertebrate Biomass/m^2	0.003 (28)	-0.015 (28)	-0.016 (28)
Percent Organic Matter	0.098 (26)	0.009 (26)	0.001 (26)
Prey Fish Biomass	-0.374 (33)	-0.217 (33)	-0.387 (33)

Table 101.3.17. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL) young of year, YOY (< 100 mm TL), and total black basses (smallmouth, largemouth, and spotted basses) biomasses and independent environmental parameters using only the stations where black basses were present. Values in parentheses are the number of paired station samples.

Environmental Parameter	Large	YOY	Total
Crayfish Biomass (wt./m^2)	0.211 (4)	-0.400 (4)	0.400 (4)
Invertebrate Density (Ind/m^2)	-0.476 (8)	0.156 (8)	-0.476 (8)
Medium Size Invertebrate Biomass (wt./m^2)	0.429 (8)	-0.228 (8)	0.429 (8)
Ammonia	-0.164 (7)	-0.228 (7)	-0.270 (7)
Soluble Reactive Phosphorus	-0.036 (7)	-0.108 (7)	-0.054 (7)
Turbidity	0.667 (7)	0.143 (7)	0.643 (7)
Specific Conductance	0.391 (7)	0.793 (7)	0.432 (7)
Mean Depth	-0.075 (9)	-0.075 (9)	-0.117 (9)
C.V. Velocity	-0.164 (7)	-0.523 (7)	-0.198 (7)
Channel Vegetation Cover	0.412 (7)	0.612 (7)	0.408 (7)
Total Undercut	-0.082 (7)	0.126 (7)	0.018 (7)
Total Shading	-0.072 (7)	-0.714 (7)	-0.143 (7)
Percent RB Buffer Crop	. (7)	. (7)	. (7)
Percent RB Corn	-0.515 (7)	0.412 (7)	-0.408 (7)
Percent RB Soybean	. (7)	. (7)	. (7)
Total Invertebrate Biomass/m^2	0.238 (8)	-0.012 (8)	0.238 (8)
Percent Organic Matter	0.886 (8)	0.371 (8)	0.886 (8)
Prey Fish Biomass	0.192 (9)	0.636 (9)	0.233 (9)

Table 101.3.18. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL), young of year, YOY (< 100 mm TL), and total rock basses densities and biomass with independent environmental parameters. Values in parentheses are the number of paired station samples. N/A insufficient data.

Environmental Parameters	YOY	Large	Total	Biomass YOY	Biomass Large	Biomass Total
Crayfish Biomass (wt./m^2)	0.294 (29)	-0.294 (29)	0.015 (29)	N/A	-0.294 (29)	-0.294 (29)
Invertebrate Density (Ind/m^2)	-0.040 (29)	-0.051 (29)	-0.040 (29)	-0.040 (29)	-0.051 (29)	0.051 (29)
Medium Size Invertebrate Biomass (wt./m^2)	-0.147 (28)	-0.140 (28)	-0.147 (28)	-0.147 (28)	-0.140 (28)	-0.140 (28)
Ammonia	-0.115 (32)	-0.036 (32)	-0.081 (32)	-0.076 (32)	-0.036 (32)	-0.036 (32)
Soluble Reactive Phosphorus	-0.086 (32)	-0.027 (32)	-0.000 (32)	-0.083 (32)	-0.027 (32)	0.027 (32)
Turbidity	0.504 (32)	0.256 (32)	0.397 (32)	0.398 (32)	0.256 (32)	0.256 (32)
Specific Conductance	0.304 (32)	0.213 (32)	0.193 (32)	0.394 (32)	0.213 (32)	0.213 (32)
Mean Depth	0.031 (34)	0.247 (34)	0.150 (34)	0.106 (34)	0.245 (34)	0.245 (34)
C.V. Velocity	-0.167 (32)	-0.366 (32)	-0.193 (32)	-0.392 (32)	-0.366 (32)	-0.366 (32)
Channel Vegetation Cover	0.135 (32)	0.103 (32)	0.086 (32)	0.209 (32)	0.103 (32)	0.103 (32)
Total Undercut	0.097 (32)	0.095 (32)	0.029 (32)	0.208 (32)	0.095 (32)	0.095 (32)
Total Shading	0.129 (32)	0.009 (32)	0.158 (32)	-0.055 (32)	0.009 (32)	0.009 (32)
Percent RB Buffer Crop	-0.096 (28)	-0.120 (28)	-0.120 (28)	-0.096 (28)	-0.120 (28)	-0.120 (28)
Percent RB Corn	-0.129 (28)	-0.161 (28)	-0.161 (28)	-0.129 (28)	-0.161 (28)	-0.161 (28)
Percent RB Soybean	-0.129 (28)	-0.161 (28)	-0.161 (28)	-0.129 (28)	-0.161 (28)	-0.161 (28)
Total Invertebrate Biomass/m^2	-0.225 (28)	-0.230 (28)	-0.225 (28)	-0.225 (28)	-0.230 (28)	-0.230 (28)
Percent Organic Matter	0.133 (26)	0.136 (26)	0.133 (26)	0.133 (26)	0.136 (26)	0.136 (26)
Prey Fish Biomass	-0.117 (33)	-0.255 (33)	-0.201 (33)	-0.140 (33)	-0.256 (33)	-0.256 (33)

Table 101.3.19. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL) young of year, YOY (< 100 mm TL), and total channel catfish densities and biomass with independent environmental parameters. Values in parentheses are the number of paired station samples.

Environmental Parameters	YOY	Large	Total	Biomass YOY	Biomass Large	Biomass Total
Crayfish Biomass (wt./m^2)	-0.316 (29)	-0.226 (29)	-0.388 (29)	-0.316 (29)	-0.226 (29)	-0.388 (29)
Invertebrate Density (Ind/m^2)	0.019 (29)	-0.184 (29)	-0.201 (29)	0.013 (29)	-0.198 (29)	-0.201 (29)
Medium Size Invertebrate Biomass (wt./m^2)	-0.123 (28)	-0.052 (28)	-0.050 (28)	-0.118 (28)	-0.037 (28)	-0.050 (28)
Ammonia	0.113 (32)	-0.167 (32)	-0.061 (32)	0.124 (32)	-0.174 (32)	-0.061 (32)
Soluble Reactive Phosphorus	0.162 (32)	0.068 (32)	0.194 (32)	0.175 (32)	0.076 (32)	0.194 (32)
Turbidity	0.080 (32)	0.413 (32)	0.294 (32)	0.060 (32)	0.410 (32)	0.294 (32)
Specific Conductance	0.346 (32)	0.079 (32)	0.147 (32)	0.340 (32)	0.069 (32)	0.147 (32)
Mean Depth	0.073 (34)	0.215 (34)	0.265 (34)	0.080 (34)	0.223 (34)	0.265 (34)
C.V. Velocity	-0.276 (32)	0.023 (32)	-0.022 (32)	-0.269 (32)	0.033 (33)	-0.022 (32)
Channel Vegetation Cover	0.209 (32)	0.119 (32)	0.058 (32)	0.189 (32)	0.103 (32)	0.058 (32)
Total Undercut	0.192 (32)	0.357 (32)	0.391 (32)	0.193 (32)	0.359 (32)	0.395 (32)
Total Shading	-0.095 (32)	0.173 (32)	0.097 (32)	-0.101 (32)	0.173 (32)	0.097 (32)
Percent RB Buffer Crop	-0.096 (28)	-0.096 (28)	-0.120 (28)	-0.096 (28)	-0.096 (28)	-0.120 (28)
Percent RB Corn	-0.129 (28)	-0.129 (28)	-0.161 (28)	-0.129 (28)	-0.129 (28)	-0.161 (28)
Percent RB Soybean	-0.129 (28)	-0.129 (28)	-0.161 (28)	-0.129 (28)	-0.129 (28)	-0.161 (28)
Total Invertebrate Biomass/m^2	-0.137 (28)	-0.030 (28)	-0.062 (28)	-0.138 (28)	-0.013 (28)	-0.062 (28)
Percent Organic Matter	0.004 (26)	0.076 (26)	0.043 (26)	-0.004 (26)	0.081 (26)	0.043 (26)
Prey Fish Biomass	0.213 (33)	-0.115 (33)	-0.014 (33)	0.214 (33)	-0.126 (33)	-0.034 (33)

Table 101.3.20. Results of Spearman Rank Correlation analyses between large (≥ 100 mm TL), young of year, YOY (< 100 mm TL), and total grass pickerel densities and biomass with independent environmental parameters. Values in parentheses are the number of paired station samples.

Environmental Parameters	YOY	Large	Total	Biomass YOY	Biomass Large	Biomass Total
Crayfish Biomass (wt./m^2)	-0.198 (29)	-0.364 (29)	-0.373 (29)	-0.200 (29)	-0.353 (29)	-0.363 (29)
Invertebrate Density (Ind/m^2)	0.262 (29)	-0.117 (29)	-0.050 (29)	0.262 (29)	-0.153 (29)	-0.109 (29)
Medium Size Invertebrate Biomass (wt./m^2)	-0.007 (28)	0.066 (28)	0.076 (28)	-0.008 (28)	0.076 (28)	0.081 (28)
Ammonia	-0.076 (32)	-0.140 (32)	-0.100 (32)	-0.085 (32)	-0.169 (32)	-0.106 (32)
Soluble Reactive Phosphorus	-0.336 (32)	-0.089 (32)	-0.116 (32)	-0.337 (32)	-0.086 (32)	-0.107 (32)
Turbidity	0.012 (32)	-0.012 (32)	0.029 (32)	0.009 (32)	0.084 (32)	0.092 (32)
Specific Conductance	0.220 (32)	0.209 (32)	0.277 (32)	0.221 (32)	0.217 (32)	0.263 (32)
Mean Depth	-0.191 (34)	0.255 (34)	0.217 (34)	-0.194 (34)	0.272 (34)	0.246 (34)
C.V. Velocity	0.197 (32)	0.012 (32)	0.018 (32)	0.196 (32)	0.015 (32)	0.020 (32)
Channel Vegetation Cover	-0.161 (32)	-0.222 (32)	-0.248 (32)	-0.161 (32)	-0.175 (32)	-0.193 (32)
Total Undercut	-0.282 (32)	0.303 (32)	0.245 (32)	-0.282 (32)	0.340 (32)	0.297 (32)
Total Shading	-0.300 (32)	0.121 (32)	0.045 (32)	-0.301 (32)	0.117 (32)	0.077 (32)
Percent RB Buffer Crop	-0.096 (28)	-0.089 (28)	-0.097 (28)	-0.096 (28)	-0.105 (28)	-0.105 (28)
Percent RB Corn	-0.129 (28)	-0.190 (28)	-0.203 (28)	-0.129 (28)	-0.190 (28)	-0.190 (28)
Percent RB Soybean	0.594 (28)	0.007 (28)	0.046 (28)	0.594 (28)	-0.033 (28)	-0.020 (28)
Total Invertebrate Biomass/m^2	0.068 (28)	-0.198 (28)	-0.158 (28)	0.066 (28)	-0.159 (28)	-0.154 (28)
Percent Organic Matter	-0.379 (26)	-0.156 (26)	-0.168 (26)	-0.387 (26)	-0.107 (26)	-0.104 (26)
Prey Fish Biomass	0.251 (33)	-0.149 (33)	-0.124 (33)	0.253 (33)	-0.172 (33)	-0.142 (33)

relationship with crayfish biomass which is somewhat surprising given their apparent insignificance in the diet of channel catfish (see earlier section). Adult densities and biomass were also strongly influenced by turbidity (Table 101.3.19). Again, this appears to be related to the tendency for channel catfish to be found in the larger streams which were generally characterized by higher turbidity values. These results are also similar to those for grass pickerel (Table 101.3.20) although this species was more often found in smaller streams with undercut banks and overhanging vegetation. Crayfish were also an important item in the diets of grass pickerel (see earlier section) and may be limiting the abundance of grass pickerel as is evidenced by the negative relationship between the two (Table 101.3.20).

In general, these results indicate that physical habitat parameters are likely to be limiting the distribution and abundance of most sportfish in Champaign County streams. The results further indicate that the limited physical habitat is a function of agricultural practices, particularly channelization and channel maintenance. The fact that little change has occurred in the amount of land in agriculture over the past thirty years (see Job 101.2) further indicates physical habitat in addition to water quality limited the distribution of sportfish for some time. The relative lack of importance of water quality parameters in the present study compared to the indirect evidence available from examining comments made during the previous study (Larimore and Smith 1963), suggests that some progress has been made in improving the water quality conditions of Champaign County streams. The apparent adverse impacts of ammonia-N on fish communities in the present study, however, indicates that non-point source inputs associated with agriculture practices, including the application of fertilizers, still pose a problem to sportfish populations. Finally, the negative relationship between the density and biomass of several sportfish and the abundance of their prey, especially crayfish, suggests that food may also be limiting the abundance of sportfish.

STUDY 102. EFFECTS OF DROUGHT ON STREAM FISHES

INTRODUCTION

Warm water stream organisms are periodically exposed to severe environmental fluctuations that can dramatically influence population densities and distribution patterns. Barring catastrophic pollution, severe droughts may be the principal modifier of stream fish populations in the Midwest. Drought effects are not localized like most anthropogenic impacts. Therefore, the geographic scale of the effects might alter the structure of the fish communities and the rates of recovery processes in a different fashion than that observed with more localized impacts.

While severe droughts are infrequent, they probably affect larger size species for a number of years following their occurrence. In many instances, these species are of particular interest to the sport fisherman. In addition, the recovery of prey species, including invertebrates, affects the productivity of predaceous sport-fish populations. The fisheries manager, while concerned with the immediate loss of stream fauna due to the drought, is also interested in the rate of colonization of fish in impacted streams when normal flows resume, and the subsequent fish productivity of the survivors and their progeny in the stream network.

Our poor understanding of drought impacts on fish populations and their subsequent recovery can be attributed to insufficient large-scale information on physical, chemical, and biological conditions that existed prior to the drought relative to those that exist during or immediately after a drought event. During the summer of 1988, east-central Illinois was subjected to a severe drought that has dramatically altered hydrological conditions within all major drainage networks. The extensive biological and physical habitat information collected in Study 101 prior to the drought provided an unusual opportunity to assess the impacts of the drought on stream-fish populations and their environment in east-central Illinois.

From the fisheries manager's point of view, there are two principal questions related to the impacts of drought: (1) what is the loss of stream fauna due to the drought, and (2) what is the rate of colonization of fish when flow resumes in impacted stream reaches.

STUDY 102. OBJECTIVE

Not all of the above issues can be addressed within the constraints of the resources and budget available for this study. However, the objective of this study was to quantify the effects of the 1988 drought on fish populations/communities in east central Illinois streams, with emphasis on sport fish and their prey, and to examine the recovery process of the fish community.

EFFECT OF DROUGHT ON INVERTEBRATE PREY

Changes in sportfish populations due to the onset of drought conditions may occur through both direct and indirect routes. Potential direct modifications in densities or distribution patterns include decreases in physical habitat through reductions in water depth, increased fluctuations in water temperature and changes in the concentrations of dissolved gases (e.g., dissolved oxygen). Potential indirect pathways include changes in critical resources

such as food supply or appropriate spawning areas. Due to the relatively high mobility of stream fish under normal conditions, changes in food resources at one location may not be reflective of changes in food resources across a broader area or region. Therefore, the purpose of this analysis was to assess the impact of the 1988 drought on the benthic food supply on a watershed scale.

METHODS

Benthic Macroinvertebrates

The 30 stations sampled for benthic macroinvertebrates in 1987 were re-sampled during the height of the drought in 1988 using the same methods and procedures outlined in Study 101.3. Species richness, densities, total biomass, and biomass in different size categories of macroinvertebrate prey from the 1987 survey were compared to those collected in 1988 using a paired t-test (Wilkinson 1989). To maintain the consistent error rate for multiple tests (e.g., biomass of different size categories of invertebrates) the Bonferroni procedure was employed for groups of hypotheses related to the same parameters.

Crayfish

In August, 1988 crayfish were re-sampled at the same 33 sampling stations sampled in 1987 using the same sampling methods and techniques outlined in Study 101.3. Species richness, abundance densities, and total biomass were compared using a paired t-test (Wilkinson 1989).

RESULTS

No significant differences were found in the number of benthic macroinvertebrate taxa (excluding crayfish) occurring at sampling stations between 1987 and 1988; nor, were detectable differences observed in the total abundance of macroinvertebrates per unit area (Table 102.1.1) between the two years. Similarly, no differences were observed in the total biomass of benthic macroinvertebrates per unit area of stream bottom during the two years (Table 102.1.1). Barring changes in sportfish prey preference, these results suggest that the drought of 1988 did not affect the abundance of macroinvertebrate prey on a per unit area basis; nor, was there a significant effect on the diversity of taxa. Thus, any changes in the fish community do not appear to be function of macroinvertebrate prey density. Obviously ,a decrease did occur in total available prey as a result of the reduction in total habitat available, due to the desiccation of many headwater streams.

Although the biomass per unit area did not change, it is also conceivable that the availability of macroinvertebrate prey to sportfish decreased as a result of changes in the size distribution of the prey themselves. To address the possibility that the drought may have changed the size structure of the macroinvertebrate community, we determined the biomass of three different size categories of prey during both the 1987 and 1988 sampling period. Analysis of these data (Table 102.1.1) revealed that no significant changes occurred in the biomass of macroinvertebrates in the small (< 5 mm total length) and large (> 10 mm) categories. A significantly higher biomass of medium sized (5-10 mm total length) macroinvertebrates was observed in 1988 compared with 1987. Overall these results suggest that the 1988 drought does not appear to have altered the abundance or biomass of non-crayfish benthic macroinvertebrates.

Table 102.1.1. Results of t-test comparing biological data collected in 1987 with that collected at the height of the1988 drought at stations the Vermilion River basin of Champaign County.

Parameter	df	t	p	Direction
Crayfish /M^2	32	4.183	0.000	87>88
Crayfish Biomass/M^2	32	4.280	0.000	87>88
Benthic Invertebrate Species Richness	28	1.313	0.200	87=88
Benthic Invertebrate Density/M^2	28	1.963	0.060	87=88
Benthic Biomass/M^2	28	-1.626	0.115	87=88
Percent Organic Matter	28	2.318	0.028	87>88
Biomass Small Invertebrates/M^2	28	0.779	0.443	87=88
Biomass Medium Invertebrates/M^2	28	-2.569	0.016	87<88
Biomass Large Invertebrates/M^2	28	-0.710	0.483	87=88

Because of the demonstrated importance of crayfish as a food item to many sportfish, as well as their substantially larger size, we examined the influence of the drought on the abundance of crayfish separately from other benthic macroinvertebrates. We found a highly significant difference in the abundance and biomass densities of crayfish between the two years (Table 102.1.1). Almost an order of magnitude lower density of crayfish occurred during the 1988 drought compared with 1987 (Table 102.1.2). Potential mechanisms for this decline in crayfish densities include increased mortality associated with increased physiological stress, increased mortality associated with greater predation by fish, or behaviorally induced burrowing and aestivation to reduce physiological stress. While we cannot conclusively identify the mechanisms responsible for the decline in crayfish densities, these results are consistent with the hypothesis that the drought adversely influenced crayfish populations.

The proportion of organic matter in stream sediments can reflect the amount of food available to stream invertebrates including omnivorous crayfish. Significantly higher percentages of organic matter occurred in the sediments at sampling stations in 1987 compared with samples collected at the same sites in 1988 (Table 102.1.1). Several interrelated factors may have contributed to the distinct decrease in the proportion of organic matter during the drought including: 1) warmer summer temperatures and an associated higher microbial activity during the drought, thereby breaking down organic matter more rapidly; 2) increased consumption by consumers associated with higher metabolic rates due to warmer temperatures, and; 3) decreased allochthonous inputs of organic matter to the stream associated with reduced precipitation and runoff. Any combination of these factors may have contributed to observed difference in organic matter. The lack of a significant response in macroinvertebrates to the decreased proportion of organic matter reflects the autotrophic nature of these stream systems (Wiley et al. 1990; Munn et al. 1989).

Table 102.1.2. The mean (± standard error) of the macroinvertebrate and crayfish densities and their biomass and the percent of organic matter in the sediments in 1987 compared with those in 1988 at selected stations in Champaign County.

Parameters	(Mean ± S.E.) 1987	(Mean ± S.E.) 1988
Benthic Density/M^2	16066.3 ± 3611.5	6563.16 ± 2135.74
Benthic Total Biomass/M^2	7227.7 ± 3414.5	44406.7 ± 18484.3
Biomass Small Invertebrates/M^2	594.4 ± 169.6	859.85 ± 390.48
Biomass Medium Invertebrates/M^2	613.9 ± 224.0	8742.39 ± 3462.9
Biomass Large Invertebrates/M^2	6019.4 ± 3398.7	29169.0 ± 16661.1
Benthic Species Richness	13.97 ± 1.81	11.55 ± 1.51
Crayfish Density/M^2	4.12 ± 1.185	0.788 ± 0.215
Crayfish Biomass/M^2	2.046 ± 0.447	0.598 ± 0.172
Percent Organic Matter	2.453 ± 0.612	1.539 ± 0.244

EFFECTS OF DROUGHT ON PHYSICAL HABITAT PARAMETERS

The most obvious effects of a drought would be on physical habitat conditions. Reductions in the length of inundated stream channels were observed as a result of the drying of small headwater streams. The degree of channel desiccation within a region would be expected to vary with the duration of the drought. We address this issue in the section concerned with the impacts of the drought on fish populations. Our goal in this section was to assess the average difference in habitat conditions at a sub-set of sampling stations in the Vermilion River basin.

METHODS

We assessed habitat conditions at 33 stations that were sampled during July and August, 1987, in July and August, 1988. This period corresponded to the height of the drought. Habitat parameters assessed at each station included mean depth, substrate size, penetrability, and velocity, the coefficient of variation in depth, substrate size, penetrability, and velocity, mean stream width, percent of water surface covered by canopy, bankside (left and right) cover ratings, percent of channel covered with vegetation, left and right bank undercut, vegetation overhang, vegetation stability, and water depth, and total reach shading. The same reaches and procedures (see Job 101.2) used in 1987 were employed. Transformed (natural logarithm) values of each habitat parameter for each station and year were compared using a paired t-test (Wilkinson 1989). To maintain the overall comparison error rate (i.e., 0.05) for multiple hypotheses related to the same parameter (e.g., left and right bank stream side cover rating) the Bonferroni procedure was employed.

RESULTS

We were unable to detect significant differences in nine of the 22 habitat parameters measured during the two annual habitat assessment periods (Table 102.1.3). Because many of the parameters were riparian (bank stability), or, are controlled by major hydrological events (e.g., degree of undercut banks), a limited number of changes would be expected to occur in habitat conditions during the drought . Our inability to assess differences in several parameters such as the amount of undercut banks and bank vegetative stability attests to the general replicability of the methodologies employed.

The lack of a significant difference in the average depth and average channel width between the two years was, however, surprising (Table 102.1.3). Despite the lack of change in mean depth, the variability in depth decreased in 1988 compared with 1987. Similarly, the depth of water at the bank was significantly less in 1988 than in 1987 (Table 102.1.3). These results suggest that important changes in the depth characteristics of the stream channels did occur as a result of the drought, but that these changes were not detectable by simply measuring mean depth. In contrast to these changes in depth, the variation in current velocity across stations remained constant, but average velocity decreased in 1988 during the drought. The lack of change in the variability in velocity is likely a function of the lack of change in stream gradient and obstructions, and minimal changes in roughness coefficients of the channel. Such a decrease in velocity in conjunction with the lack of change in average depth could be expected to have a significant effect on the reaeration capacity of low gradient streams, thereby providing an additional stress on fish populations through increased variation in the metabolism of the aquatic system (see Wiley et al. 1987 and 1990).The increase in mean substrate particle size in 1988 compared with 1987 is consistent with the decrease in the penetrability of the sediment (Table 102.1.4). Conceptually, one could expect that the settling rate of smaller sediment particles would

Table 101.2.3. Results of t-tests comparing habitat data collected in 1987 with that collected at the height of the1988 drought at stations the Vermilion River basin of Champaign County.

Parameter	df	t	p	Direction
Mean Depth	31	-0.306	0.762	87=88
C.V. Depth	31	5.666	0.000	87>88
Mean Penetrability	31	-5.664	0.000	87<88
C.V. Penetrability	31	3.131	0.004	87>88
Mean Substrate	28	-6.609	0.000	87<88
C.V. Substrate	28	2.845	0.008	87>88
Mean Velocity	28	-15.047	0.000	87>88
C.V. Velocity	28	0.339	0.737	87=88
Reach Length	31	3.727	0.001	87>88
Total Width	31	0.530	0.600	87=88
Habitat Rating	31	2.247	0.032	87>88
Percent Canopy	31	-4.225	0.000	87<88
LB Stream Side Cover Rating	31	1.748	0.090	87=88
RB Stream Side Cover Rating	31	2.319	0.027	87=88
Percent C.V. Cover	31	-8.060	0.000	87<88
LB Undercut	31	0.122	0.904	87=88
RB Undercut	31	-0.063	0.950	87=88
LB Vegetation Overhang	31	-4.497	0.000	87<88
RB Vegetation Overhang	31	-5.478	0.000	87<88
LB Vegetation Stability	31	-1.375	0.179	87=88
RB Vegetation Stability	31	-1.153	0.258	87=88
LB Water Depth	31	5.727	0.000	87>88
RB Water Depth	31	6.100	0.000	87>88
Percent Total Shade	31	-4.680	0.000	87<88

Table 102.1.4. The average (± sandard error) of each habitat parameter collected at selected stations in 1987 and 1988 in Champaign County.

Parameter	1987	1988
Mean Depth (cm)	20.0 ± 2.82	20.15 ± 2.63
C.V. Depth	73.5 ± 6.40	45.66 ± 2.87
Mean Penetrability	2.412 ± 0.181	2.70 ± 0.16
C.V. Penetrability	57.40 ± 7.42	23.69 ± 2.17
Mean Substrate	2.46 ± 0.17	2.96 ± 0.16
C.V. Substrate	53.52 ± 7.75	20.47 ± 2.24
Mean Velocity (M/sec)	0.106 ± 0.02	0.056 ± 0.012
C.V. Velocity	107.775 ± 16.045	130.51 ± 17.77
Reach Length (M)	73.606 ± 5.134	45.39 ± 2.54
Total Width (M)	11.382 ± 1.220	10.47 ± 1.32
Habitat Rating	1.23 ± 0.09	1.025 ± 0.135
Percent Canopy	14.69 ± 3.75	25.5 ± 5.12
LB Stream Side Cover Rating	2.36 ± 0.104	2.14 ± 0.13
RB Stream Side Cover Rating	2.43 ± 0.085	2.18 ± 0.08
Percent Channel Vegetation Cover	2.52 ± 1.83	30.73 ± 5.24
LB Undercut	1.70 ± 0.72	0.92 ± 0.31
RB Undercut	1.59 ± 0.70	1.069 ± 0.32
LB Vegetation Overhang	24.16 ± 5.96	66.70 ± 13.59
RB Vegetation Overhang	21.85 ± 5.71	77.25 ± 15.89
LB Vegetation Stability	3.02 ± 0.193	3.18 ± 0.18
RB Vegetation Stability	3.06 ± 0.171	3.16 ± 0.14
LB Water Depth	4.39 ± 0.684	1.27 ± 0.38
RB Water Depth	5.31 ± 0.700	2.41 ± 0.76
Percent Total Shade	20.20 ± 3.96	47.50 ± 4.94

increase with decreasing velocity, thereby increasing rates of sedimentation and decreasing mean sediment particle size. In contrast to this expectation, we observed an increase in sediment size (Table 102.1.4) during the drought which is consistent with the idea that reductions in overland flow due to the absence of precipitation is reducing the transport of sediment from the watershed to the stream channel. This would effectively decrease the total sediment load carried by the water. This reduction in sediment load should increase the kinetic energy of the stream which, in turn, increases the shear stress imposed on the substrate. This could allow for the transport of smaller, previously settled sediments.

The final major change in habitat condition that occurred during the drought was an increase in the amount of overhanging vegetation, canopy cover, shading, and in-channel vegetation (Tables 102.2.3 and 102.2.4). Increases in several of these parameters, particularly overhanging vegetation along stream banks, should provide additional refuge for many smaller fish. The increase in in-channel vegetation cover reflects the increase in the standing crop of algae which was obviously more abundant during the summer of 1988 than it was in 1987.

MACROINVERTEBRATE COMMUNITIES FOLLOWING THE DROUGHT

The rate of recolonization of biological communities following a disturbance vary with the the degree and type of disturbance (Pickett and White 1985), the life history and behavioral characteristics of the members of the community of interest, and with the proximity of a recolonizing pool. Previous comparisons of benthic macroinvertebrate samples collected in 1988 with those collected in 1987 revealed no apparent impact of the 1988 drought on the standing crop, species richness, or densities of aquatic macroinvertebrates in reaches that remained inundated with water (see earlier section). As mentioned, however, the greatest impact of the drought was likely associated with the total loss of area of inundated stream when some reaches became very shallow or completely desiccated. Desiccation would have obvious impacts on benthic communities. Because of their importance as a food resource, the presence of aquatic macroinvertebrates in sufficient quantities may dictate the rate of reestablishment of the fish community. Therefore, throughout 1989 we monitored the structure of the aquatic macroinvertebrate communities in three sampling reaches (Figure 102.1.1) that had been to desiccated during the 1988 drought in an attempt to assess the rate of recovery of the communities. These sampling reaches were located in Scum Creek (Figure 102.1.1a), Sugar Creek (Figure 102.1.1b), both within Champaign County, and Jordan Creek (Figure 102.1.1c) located in Vermilion County.

METHODS

Benthic macroinvertebrates were sampled as reported in Job 101.3 except only three replicate samples were collected at each of seven sampling locations instead of five replicate samples at each station. Four sampling locations in Scum Creek (1096U, 1096D, SCUM-1604, and SCUM-1606), three locations in Sugar Creek (1157U,SUGR-1703,and SUGR-1705), and one station in Jordan Creek (JORD-2015), Vermilion County were sampled periodically in 1989 to assess recovery of the macroinvertebrate community from the drought. Samples were collected on roughly a seasonal basis; thus, substantial natural, intra-annual variation in each of the parameters associated with the life histories of the organisms is to be expected. All benthos were preserved in 7% formalin and samples returned to the laboratory.

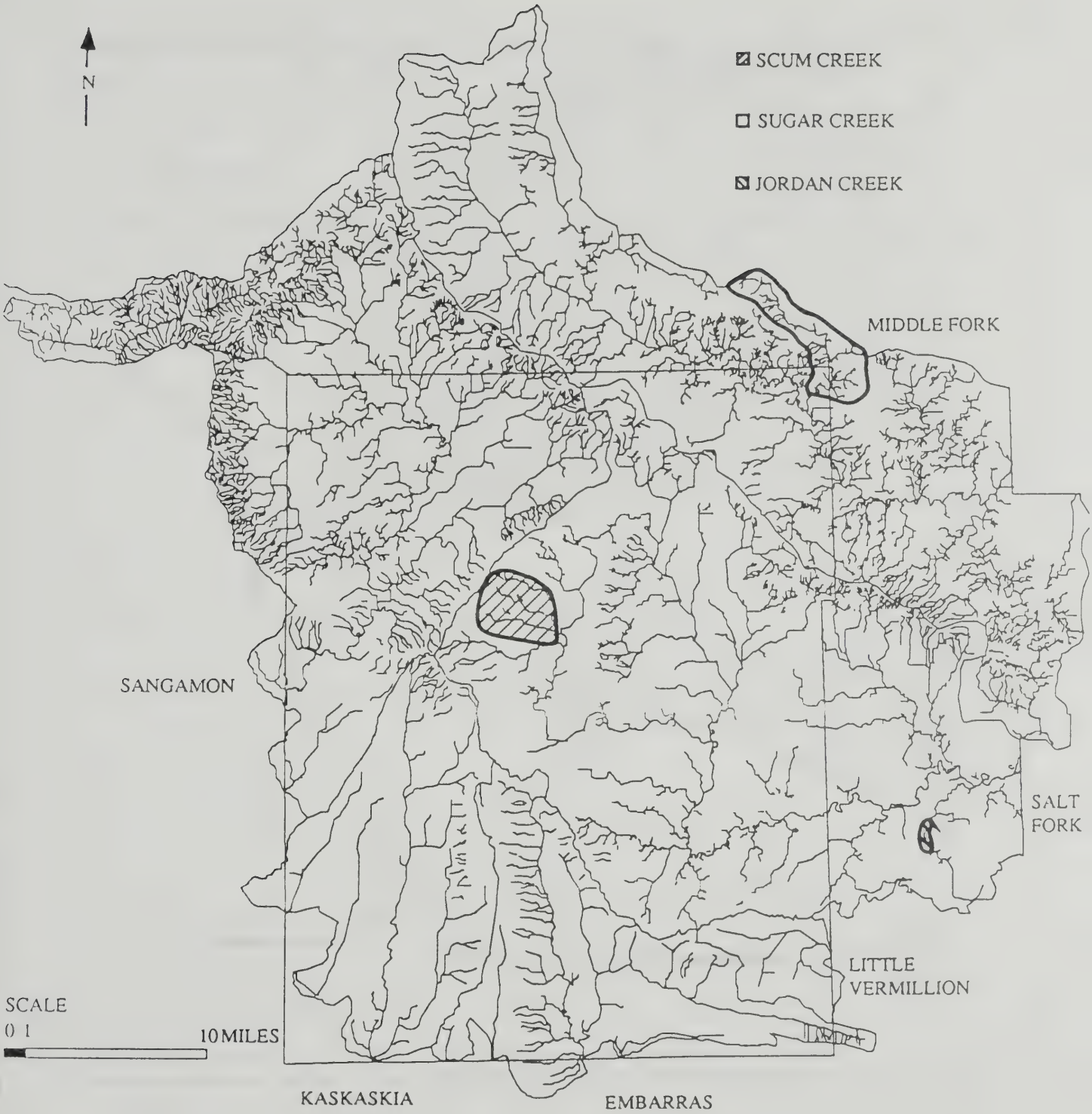


Figure 102.1.1. Six major drainage areas and the location of the three primary drought recovery streams.

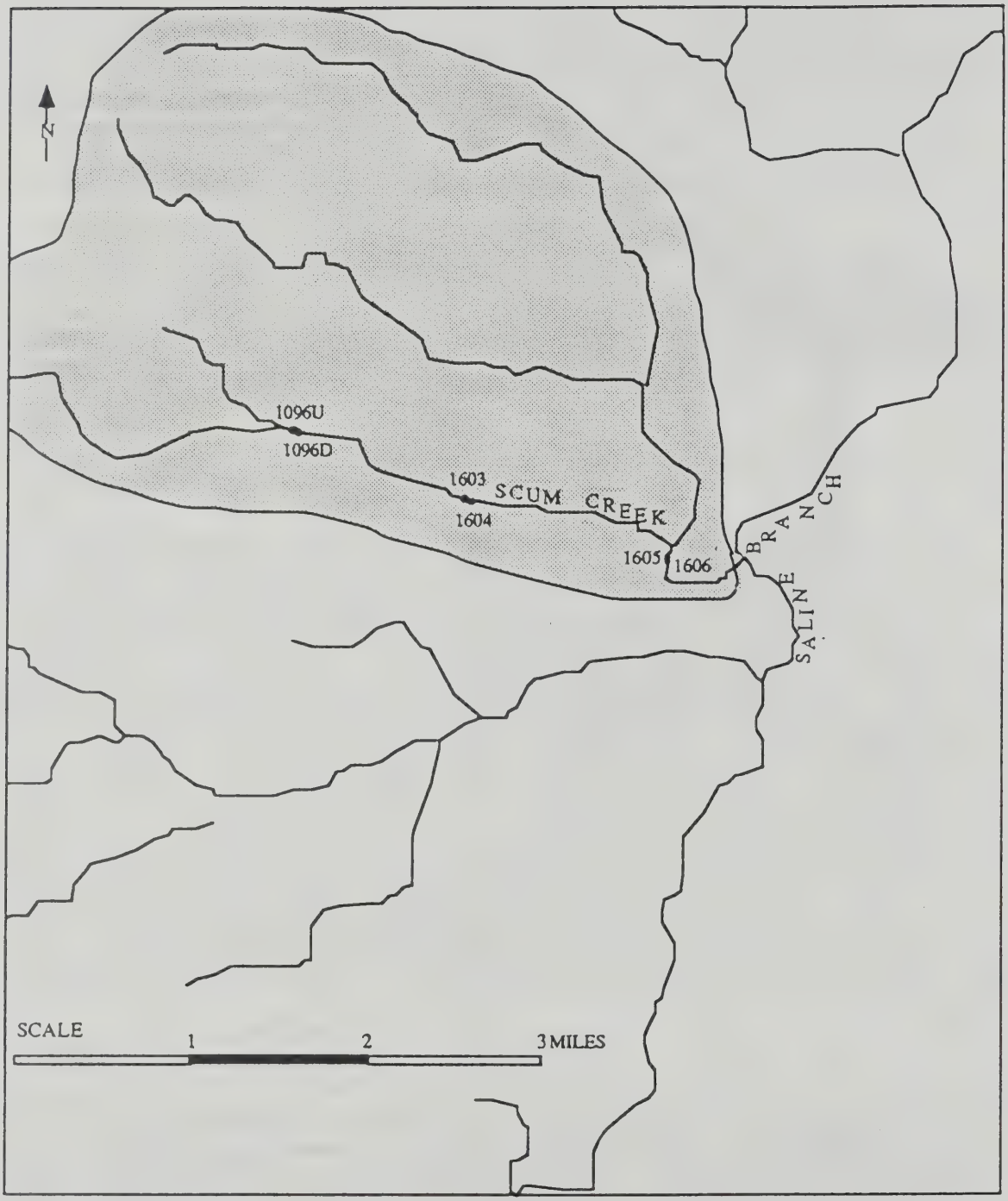


Figure 102.1.1a. Specific sampling locations in Scum Creek. Shaded area represents dessicated area.

Figure 102.1.1b. Specific sampling locations in Sugar Creek. Shaded area represents dessicated area.

Figure 102.1.1c. Specific sampling locations in Jordan Creek. Shaded area represents dessicated area.

Macroinvertebrates were identified to the lowest practical taxon except for chironomids which were identified only to family. Densities and total biomass of each sample and within each size category (i.e., <5, 5-10, >5 mm) were determined as presented in Job 101.3. Simple plots of taxa richness and densities through time were made for each stream reach.

RESULTS

The taxa richness, percent organic matter in sediment, density of macroinvertebrates, and dry weight at each of the seven sampling stations for each 1989 sampling period are reported in Figures 102.1.2-8. In every case, time is reported as Julian day with January 1, 1989 equal to one. Because none of these specific locations were sampled during the initial macroinvertebrate survey in 1987 (see previous sections), we are unable to provide an exact assessment of when recovery was completed, if indeed it was. An estimate of community structure for the recovery stations prior to the drought can be obtained however by examining similar parameters at 1987 survey stations near to the 1989 recovery stations.

In late summer of 1987 the average density of macroinvertebrates at station 1095, located in the vicinity of the three Scum Creek stations, was 9,779 individuals/m2. A total of 14 macroinvertebrate taxa, excluding crayfish were collected, the mean dry weight of macroinvertebrates was 4,568 mg/m2, and the average proportion of organic matter in the sediments was 0.95%. Comparison of these values to those from the three Scum Creek recovery stations (Figures 102.1.2-4) indicate that the number of taxa were well within the range of that prior to the drought by the end of the study except at the SCUM-1604 site (Figure 102.1.4). The substantially lower number of taxa at this site throughout the year, in conjunction with the gradual increasing taxa richness at the site suggests that recovery may not have been completed by the fall of 1989. Both the abundance and biomass (measured as dry weight) of macroinvertebrates appears to have recovered early in 1989. Similarly, the proportion of organic matter in the sediments was similar at all three recovery sites (Figures 102.1.2 - 4). In general, these results suggest that the macroinvertebrate communities in the vicinity of Scum Creek recovered to pre-drought conditions by the end of 1989.

Data collected in 1987 from station 1156 were used to compare with 1989 data collected from the three Sugar Creek stations. We collected a total of 20 macroinvertebrate taxa and recorded an average of 3,240 individuals/m2 and 329.5 mg/m2 dry weight of macroinvertebrates at station 1156. The average proportion of organic matter in the sediments was determined to be 1.28%. Taxa richness only equaled or exceeded pre-drought conditions once in 1989 at the three Sugar Creek recovery stations (Figures 102.1.5 - 7). The exceptionally high number of taxa collected during August, 1989 (Julian day 228) at station SUGR-1705 was largely a function of sampling in an atypical riffle like area that supported a large number of taxa (Figure 102.1.6). Other than this sample, our results suggest that the taxa richness of the benthic communities in Sugar Creek had not recovered to pre-drought levels by the end of 1989. Although taxa richness did not appear to recover during this period, the densities and biomass of macroinvertebrates generally exceeded the average pre-drought levels (Figures 102.1.5 - 7). The proportion of organic matter in the substrate was also similar to, or, exceeded pre-drought levels. Relatively high densities of macroinvertebrates and low species richness is characteristic of stressed stream benthic communities (Osborne and Davies 1987). Because many of the taxa that inhabited stretches of Sugar Creek were likely eliminated from the immediate area during the period of prolonged desiccation and atmospheric exposure, the dominance of a few benthic taxa may be the result of a competitive release following the cessation of drought conditions.

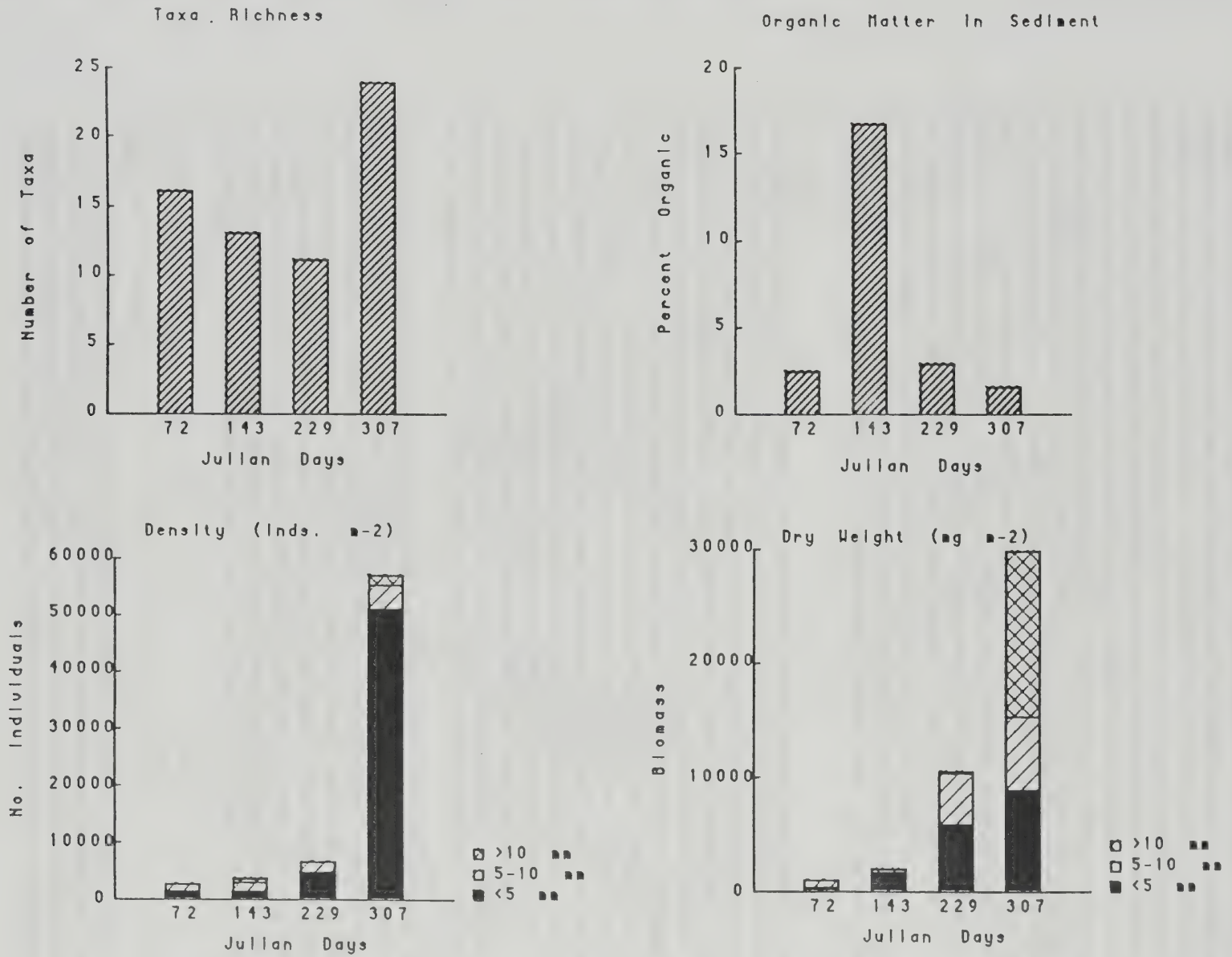


Figure 102.1.2. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station 1096 (Scum Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.

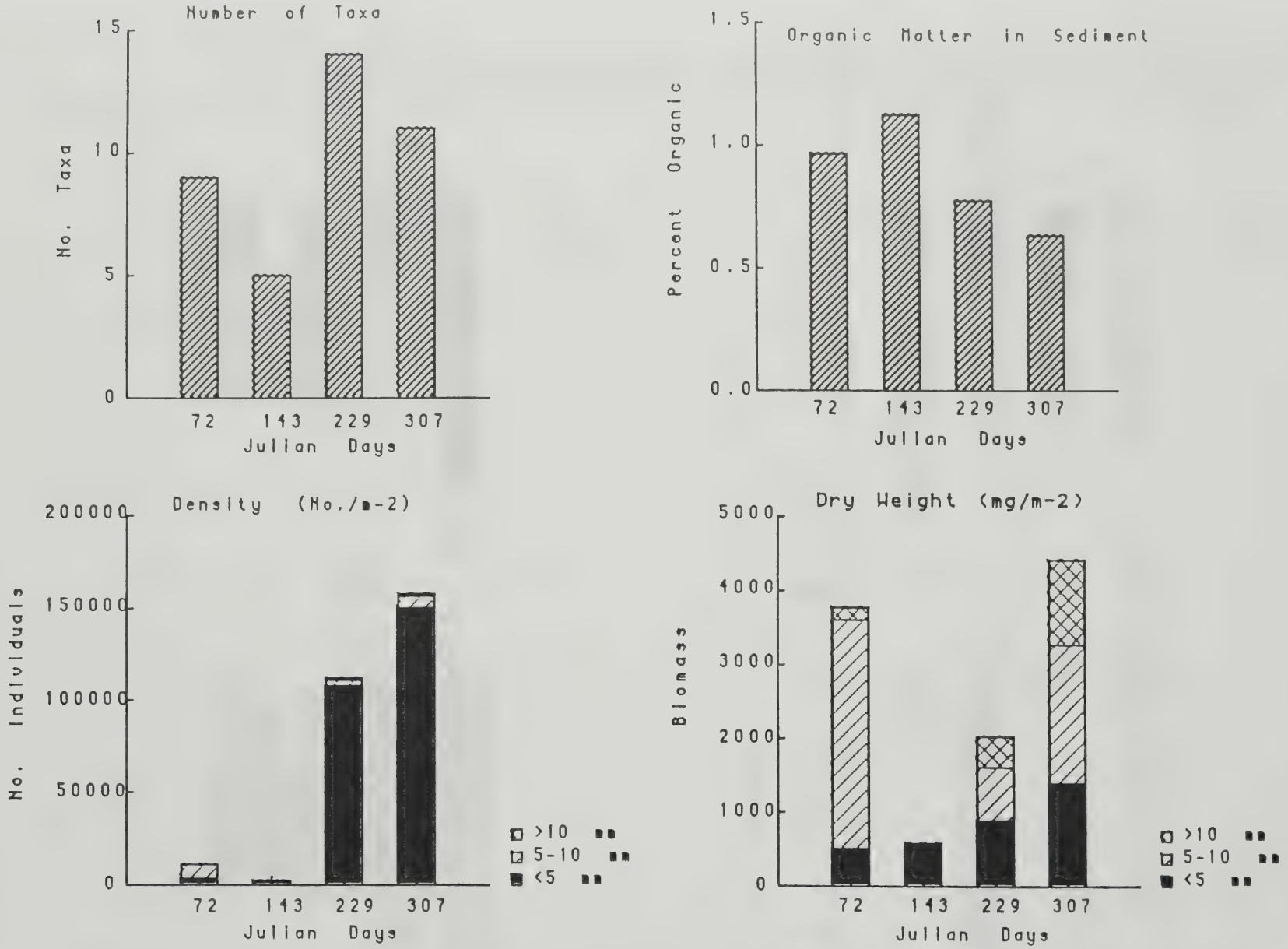


Figure 102.1.3. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station Scum-1606 (Scum Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.

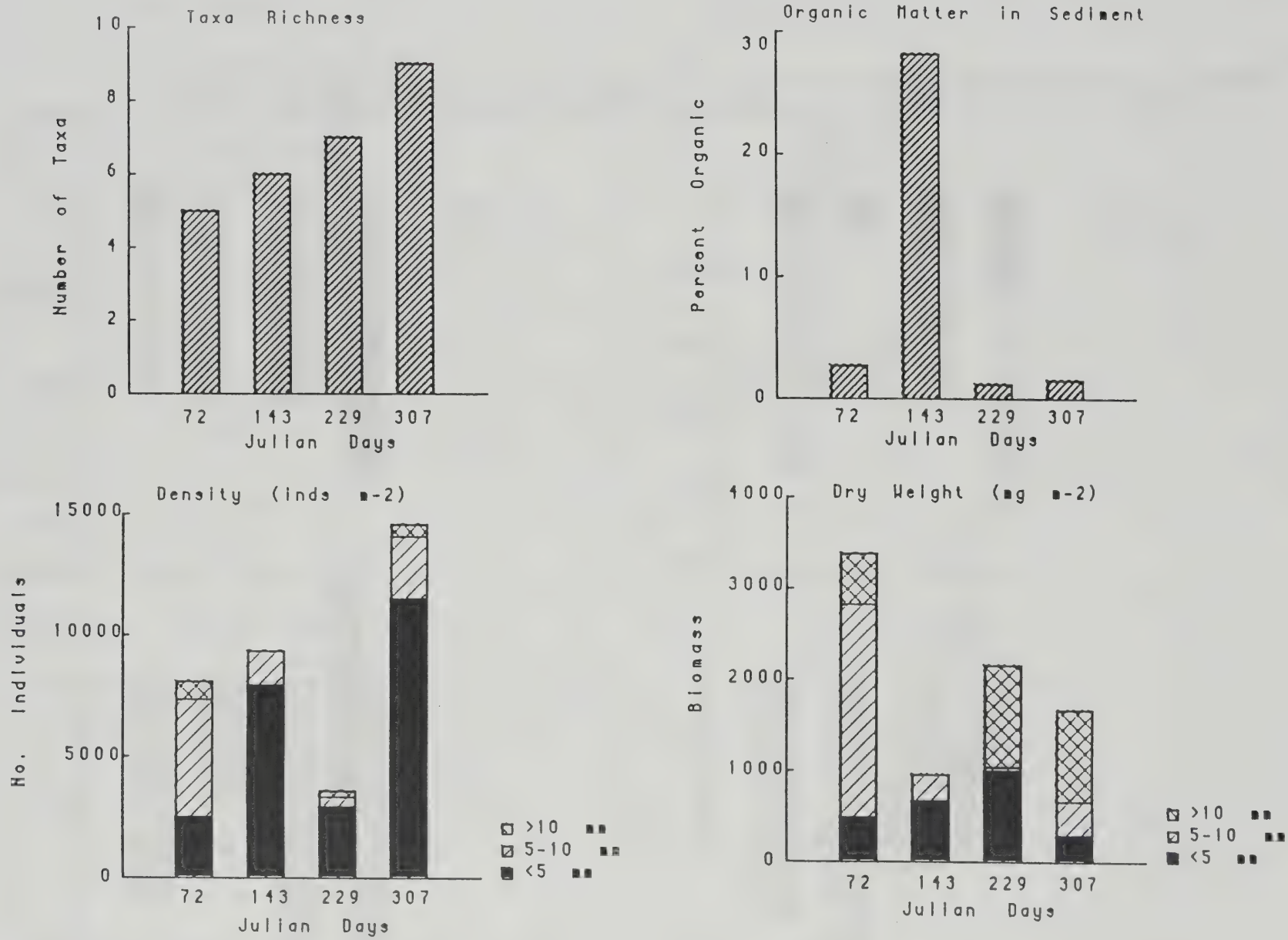


Figure 102.1.4. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station Scum-1604 (Scum Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.

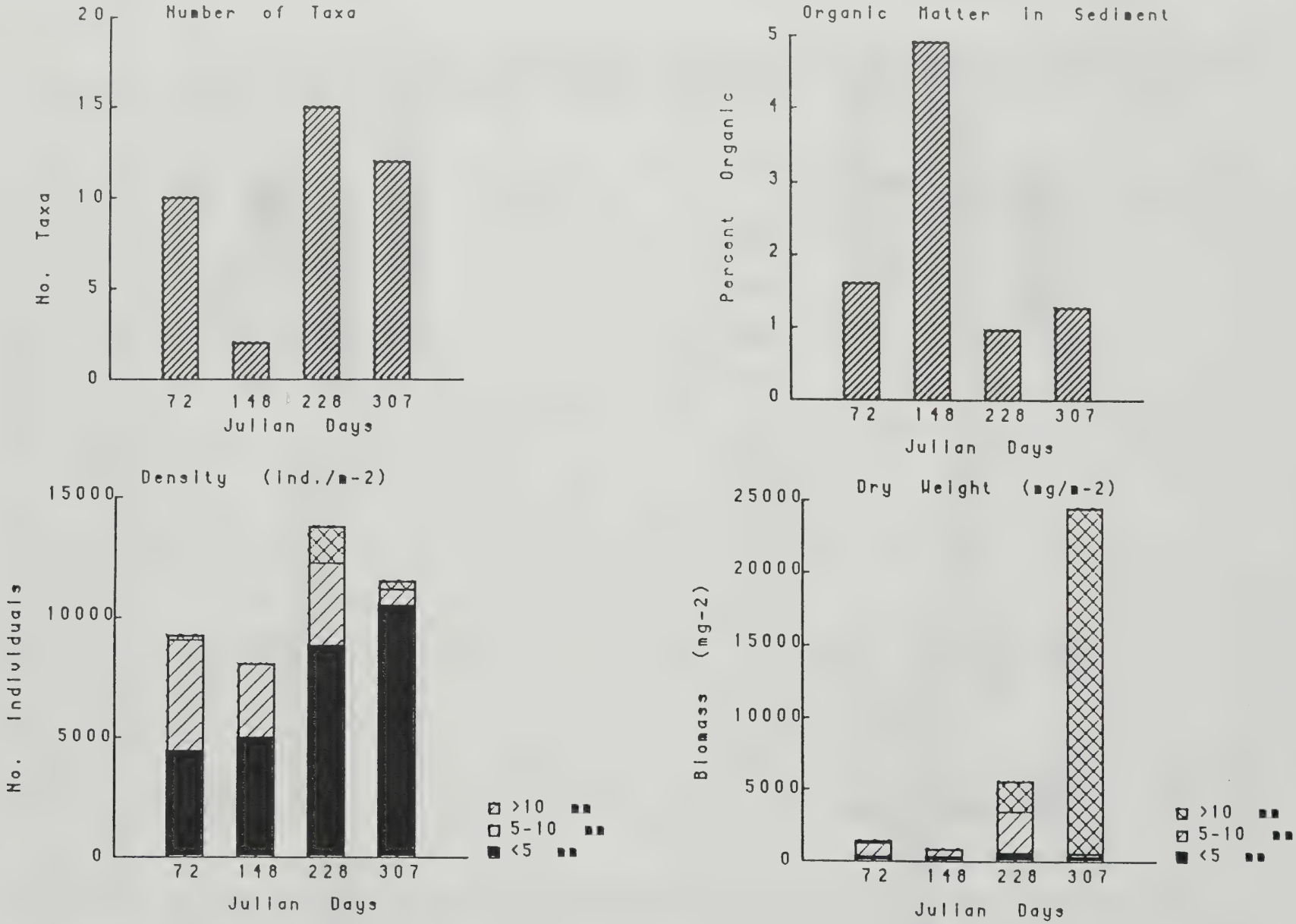
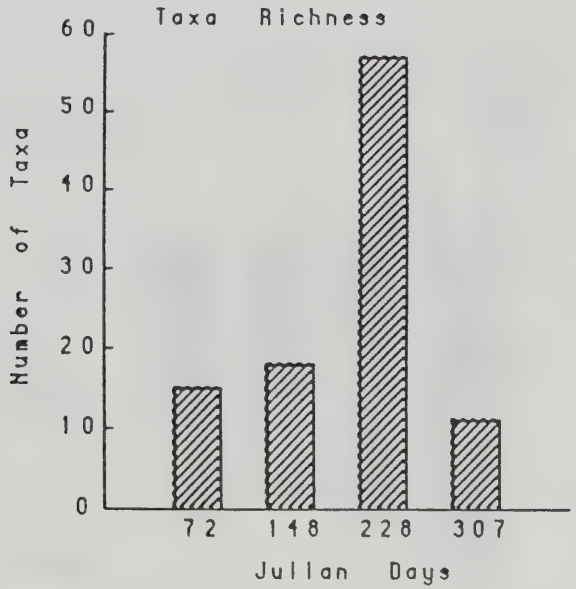
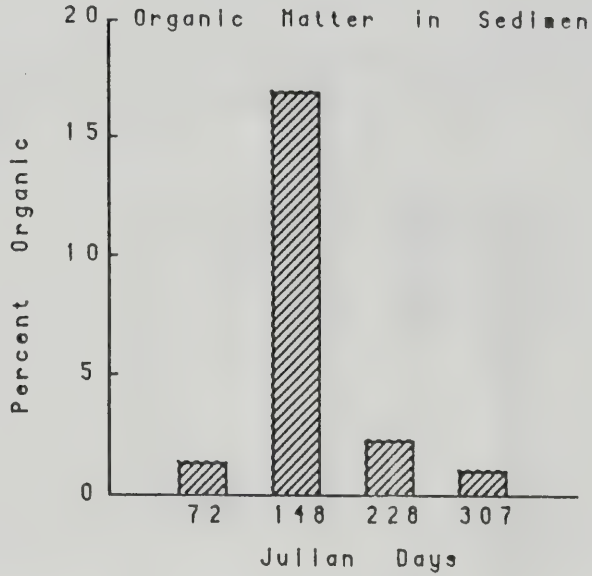
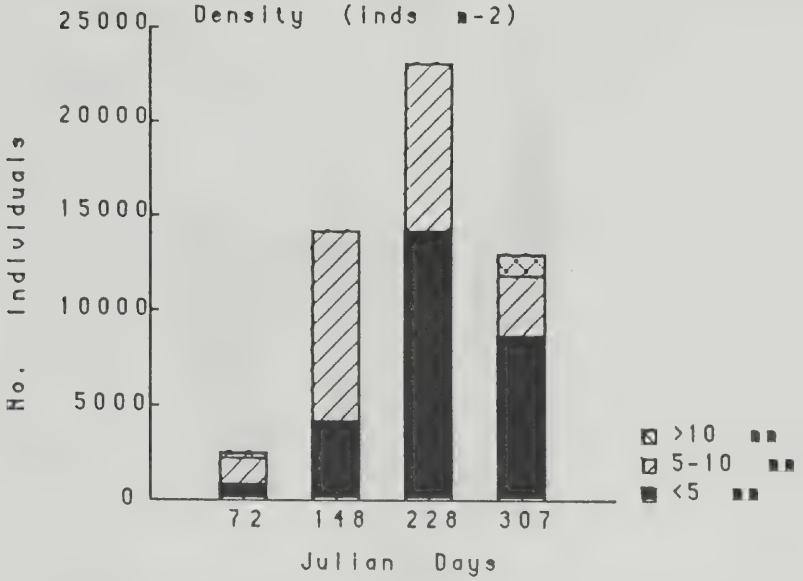


Figure 102.1.5. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station 1157 (Sugar Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.







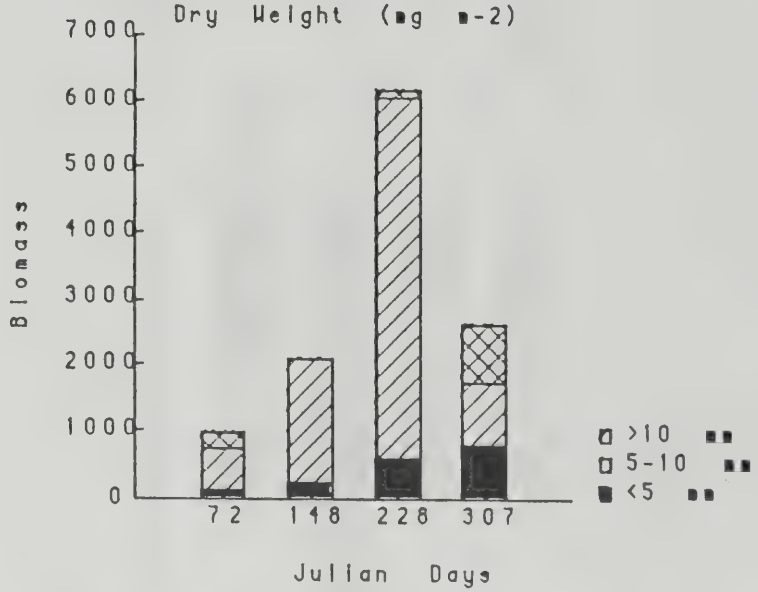


Figure 102.1.6. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station SUGR-1705 (Sugar Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.

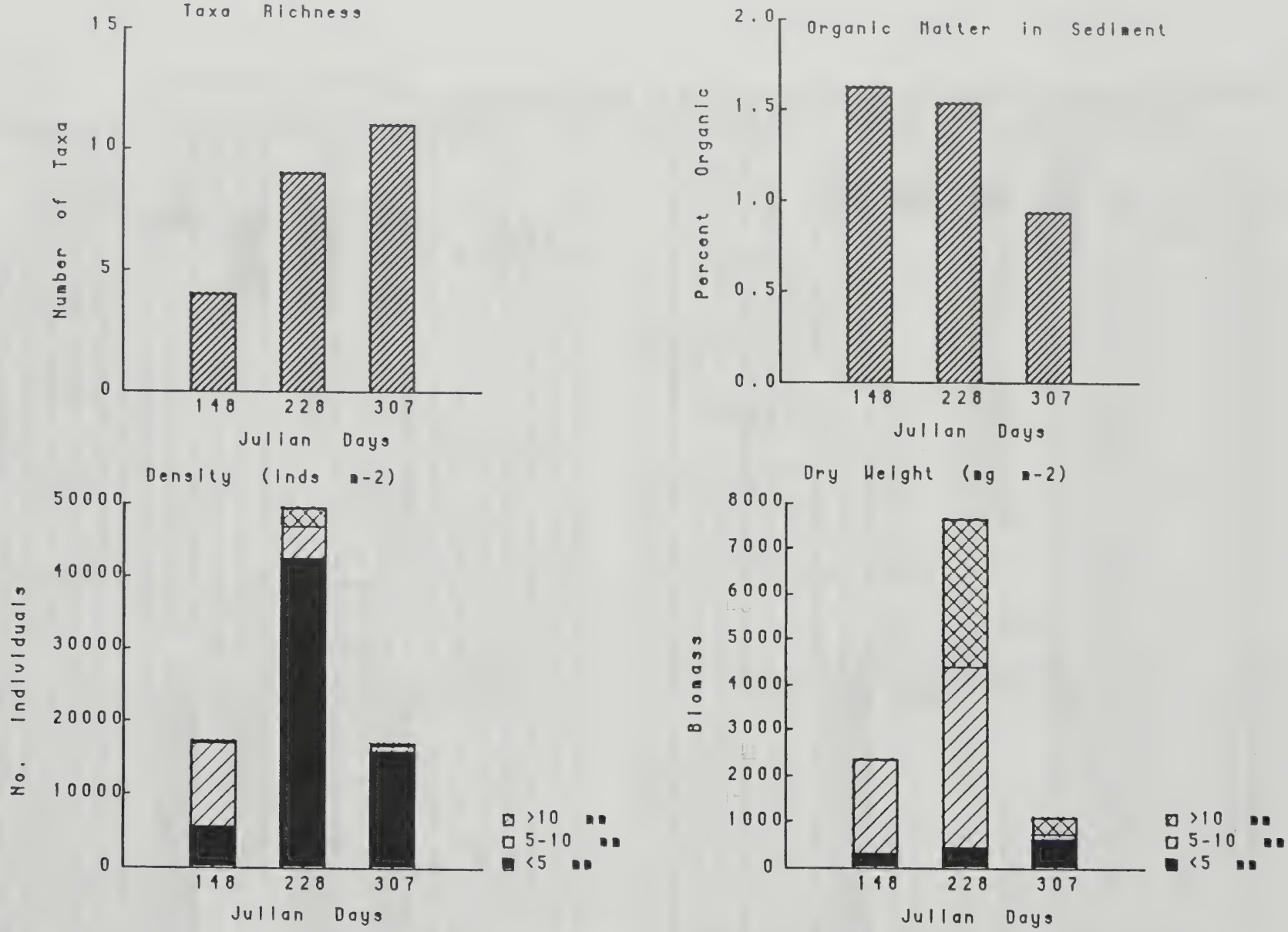
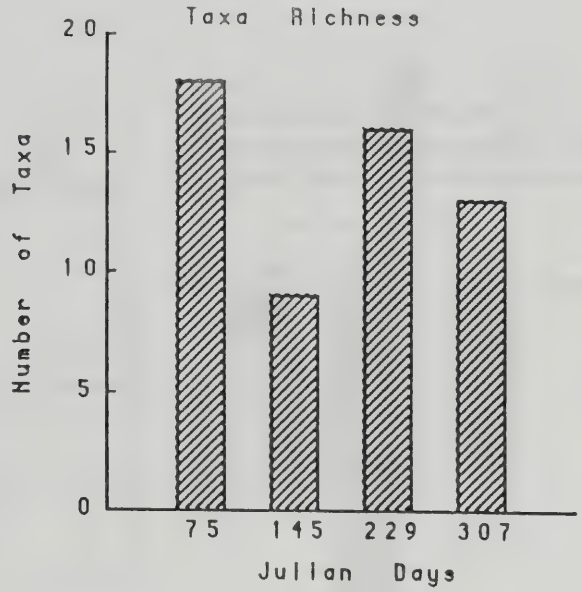
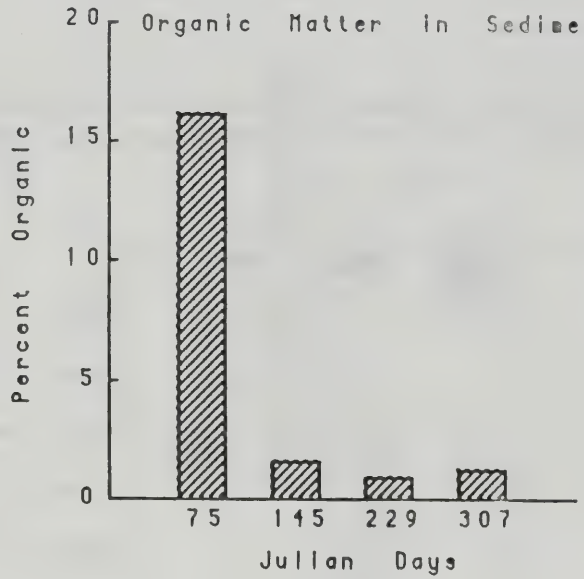
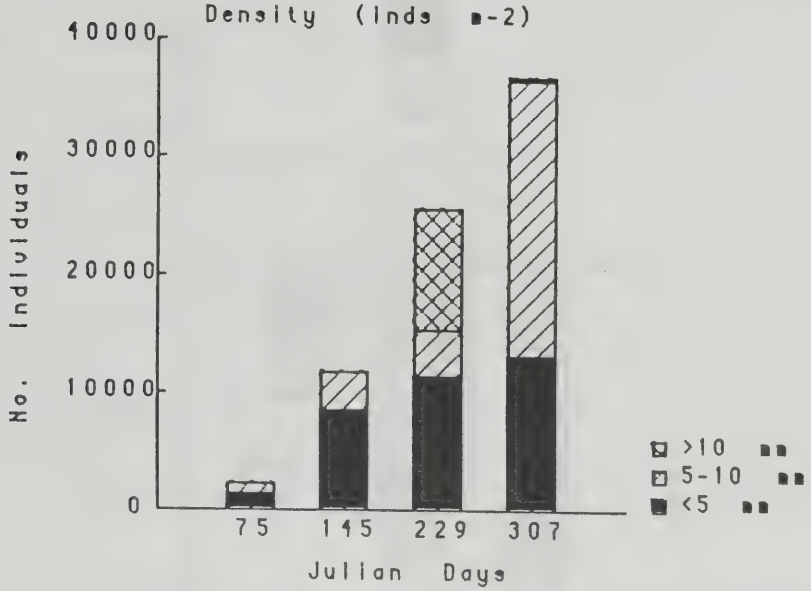


Figure 102.1.7. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station SUGR-1703 (Sugar Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.







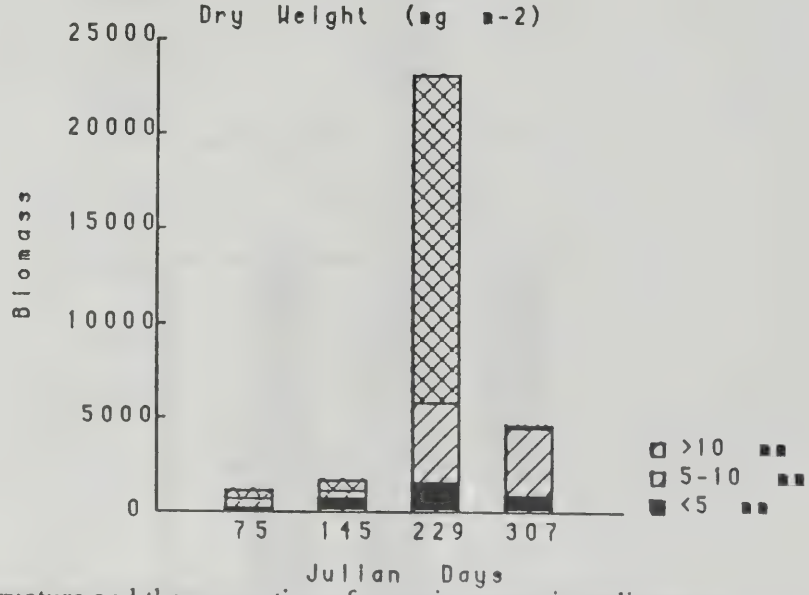


Figure 102.1.8. Recovery trends in macroinvertebrate community structure and the proportion of organic matter in sediments at station JORD-2015 (Jordan Creek) during 1989, the year following the drought. Biomass and density are reported with respect to size groups.

Whatever the mechanism, these results suggest that the structure of benthic macroinvertebrate communities in Sugar Creek had not returned to pre-drought conditions.by 1989. However, similar, or, even higher densities and standing crops of macroinvertebrates inhabited Sugar Creek in 1989. It is questionable whether such a situation would directly inhibit the recovery of sportfish population, as we were unable to find any indication of a preference for specific non-crayfish macroinvertebrate taxa by smallmouth bass. Alterations in the macroinvertebrate communities may, however, influence the abundance of smaller fish which appear to constitute up to 25% of the prey of smallmouth bass (Figure 101.3.2). The possibility of an indirect impact on smallmouth bass, or other sportfish, is conceivable, but would require that the recovery of smaller prey fish was inhibited as a result of a strong preference for specific macroinvertebrate taxa that were rare or absence in the 1989 collections. Assessment of the food habits of non-game fish were, however, beyond the scope of this project.

In 1987 we collected replicate benthic macroinvertebrate samples from two distinct habitat types in Jordan Creek, a riffle and a pool. Mean taxa richness in the riffle was 57 compared with 24 in the pool. Average densities and standing crops were 8,918 individuals/m2 and 1,352 mg dry weight/m2 in the riffle compared with averages of 5,722 individuals/m2 and 3,667 mg dry weight/m2 in the pool habitat. The JORD-2015 station was categorized as a run during our assessment of habitat conditions (see Job 101.3); our experience indicates that run habitats have a slightly less diverse benthic community structure than do either pool or a riffle habitats (Osborne and Bayley unpublished data). With this in mind, we conclude that the structure of the benthic macroinvertebrate community at JORD-2015 in 1989 was, with the possible exception of a lower taxa richness, similar to that which occurred in Jordan Creek prior to the 1988 drought (Figure 102.1.8).

The apparently lower taxa richness at JORD-2015 again suggests that some macroinvertebrate populations were indeed eliminated as a result of the drought and had not recovered prior to the final 1989 sampling period. This in association with the similar, or higher, biomass and abundance of macroinvertebrates in 1989 relative to those in 1987 are also similar to the changes in macroinvertebrate community structure that was observed in Sugar Creek. Thus, this analysis of macroinvertebrate communities in the Vermilion Basin following the prolonged 1988 drought suggests that the community structure of macroinvertebrates in two of the three streams examined had not completely recovered. Because the abundance and biomass of macroinvertebrates in all three recovery streams returned to, or exceeded pre-drought levels, it is unlikely that these observed alterations in macroinvertebrate community structure, by themselves, inhibit the recovery of sportfish populations.

COLONIZATION OF STREAMS BY FISH

INTRODUCTION

The objective was to estimate the recovery of stream fish populations following the severe drought of 1988. Sections of three streams were selected that showed typical hydrological effects of the drought in the Salt Fork/Middle Fork drainages (Figs. 102.1.1, 1a, 1b, 1c). The downstream part of these sections all drained close to 10,000 acres (15.6 mi^2).

METHODS

By the late summer of 1988 fish remaining in isolated pools were continuing to die. In particular, those fish in pools exposed to more sunlight suffered from nightly oxygen

deficits due to algae blooms. If the exposed pools had any fish remaining, they were typically dominated by yellow bullheads, blackstripe topminnows, creek chubsuckers, and common carp. All remaining pools in the sections shown in Figs. 102.1a, b, and c were treated with at least 6 ppm rotenone in September 1988 so that subsequent colonization could occur from adjoining continuous stretches. Scum and Sugar Creeks were therefore devoid of fish from their sources to 5.99 and 11.16 miles downstream, respectively, and their tributaries were dry. Jordan Creek had a pool 1.52 miles long upstream that was maintained by a series of beaver dams, so its fishless stretch was only 1.89 miles long and colonization could proceed from upstream as well as downstream.

One hundred and fifty-five standardized 30-ft electric seine samples, using one upstream and one downstream pass between block nets plus the bottom block net catch, were taken at intervals beginning in the middle of March, 1989, and were continued for two growing seasons. The intervals between samples were one week until the end of June, followed by two-week intervals until July, when the interval was extended to 4-6 weeks. The intervals were designed to account for more rapid movements expected in the spring due to higher water levels and life-history patterns, while ensuring against fishing mortality affecting the populations, especially during the low water conditions later in the year.

As a further insurance against possible fishing mortality effects, alternate sites were sampled during successive trips to each stream. Three representative sample stations along with three alternate, adjacent sites, were selected at similar intervals in Scum (Figure 102.1.1a) and Sugar (Figure 102.1.1b) Creeks. One station with an alternate was selected about midway in the Jordan Creek section (Figure 102.1.1c).

The results were averaged in contiguous 5-week intervals. Numbers and biomass were expressed on a unit stream length basis to partially account for short-term water level effects that change fish density on a unit area basis. Corrections due to gear efficiency (F-61-R, Bayley and Dowling 1990) accounted for environmental effects on catchability, among which the effects of discharge variation was most important. Some of the estimates for darters using the current efficiency formula were unrealistically high, so darters have been eliminated from this analysis. Future analyses of darters will depend on the results of a reanalysis of the calibration information for this group.

RESULTS AND CONCLUSIONS

Interpretation of the results should bear in mind that 1989 was a 'semi-drought' year. Jordan and Scum creeks maintained their flows, although Scum virtually stopped in the summer of 1989. The flow of Sugar Creek stopped flowing in July, which was partly due to the assistance of a beaver. In contrast, the spring of 1990 provided above average discharges, which succeeded in modifying the channel and clearing the beaver dam on Sugar Creek. High water delayed the start of sampling until mid-April in 1990.

The results are shown graphically in Figures 102.1.9 through 102.1.19. Observed species richness (Fig. 102.1.9) peaked in May, June, and December in Scum, Sugar, and Jordan Creeks, respectively. Peaks at similar times, which were attained at similar rates, is suggested by the graphs for Scum and Sugar Creeks. Only Scum creek suggested a higher

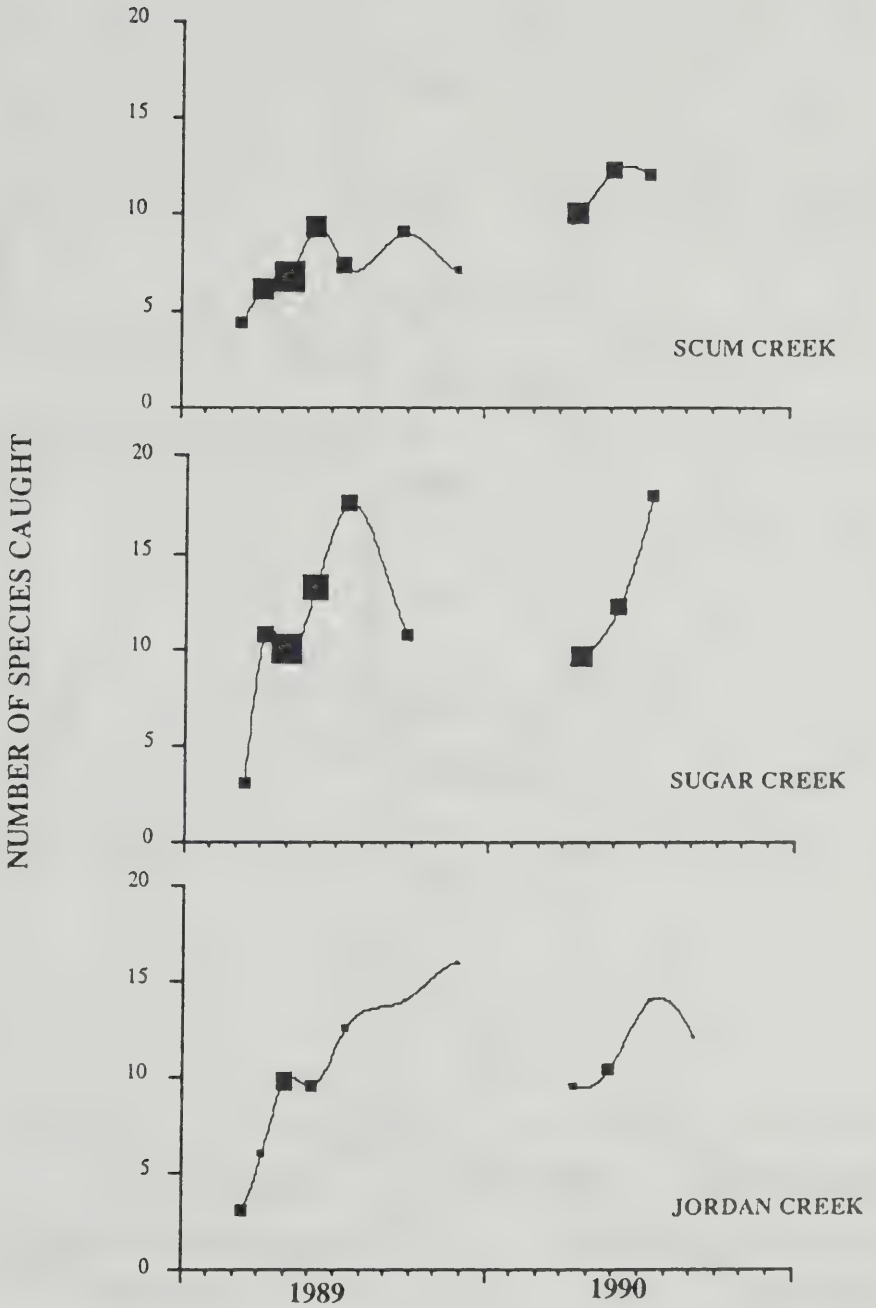


Figure 102.1.9 Number of species caught during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

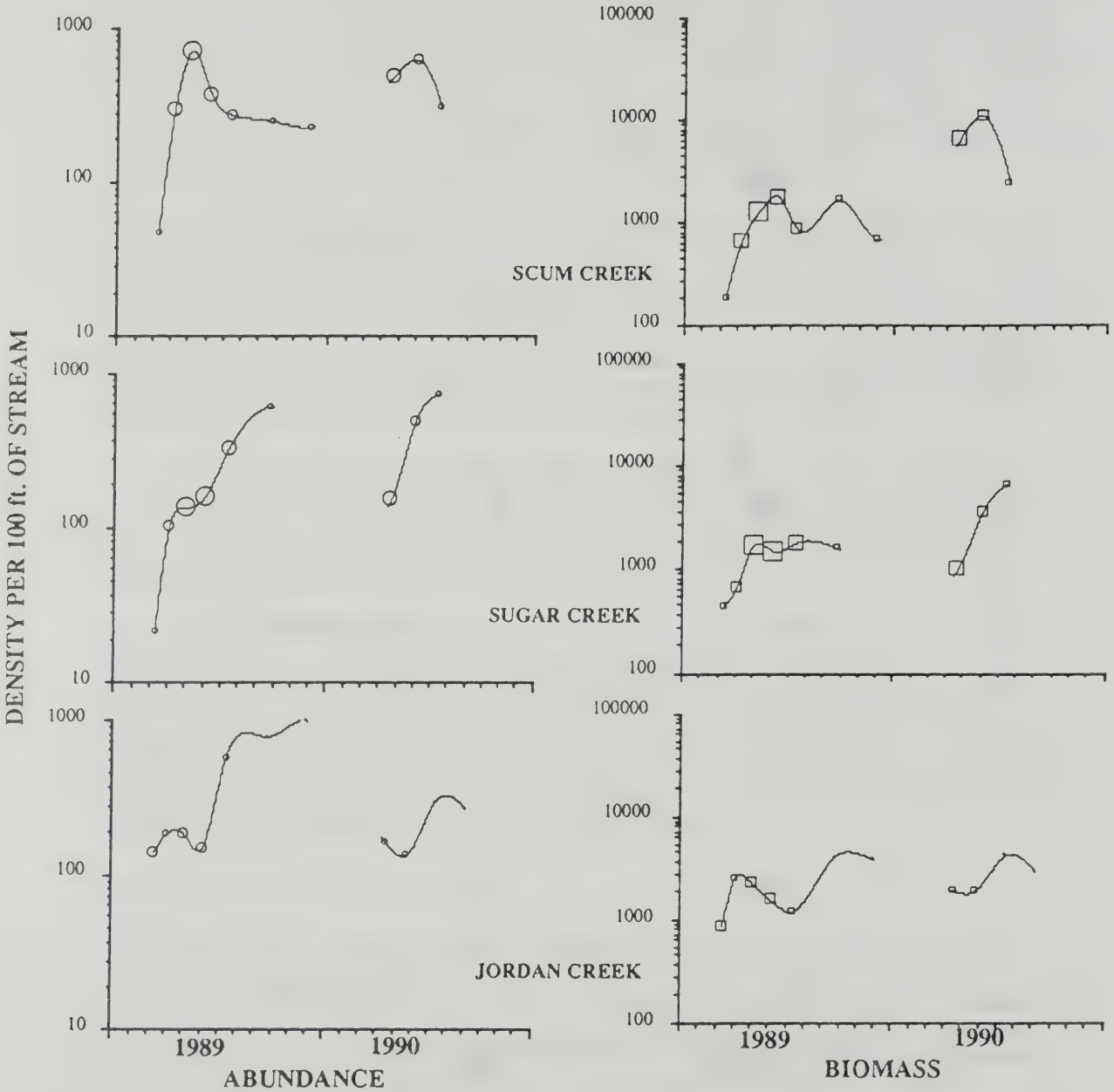


Figure 102.1.10 Abundance density (left) and biomass density (right) of non-darters; (= numbers or biomass of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

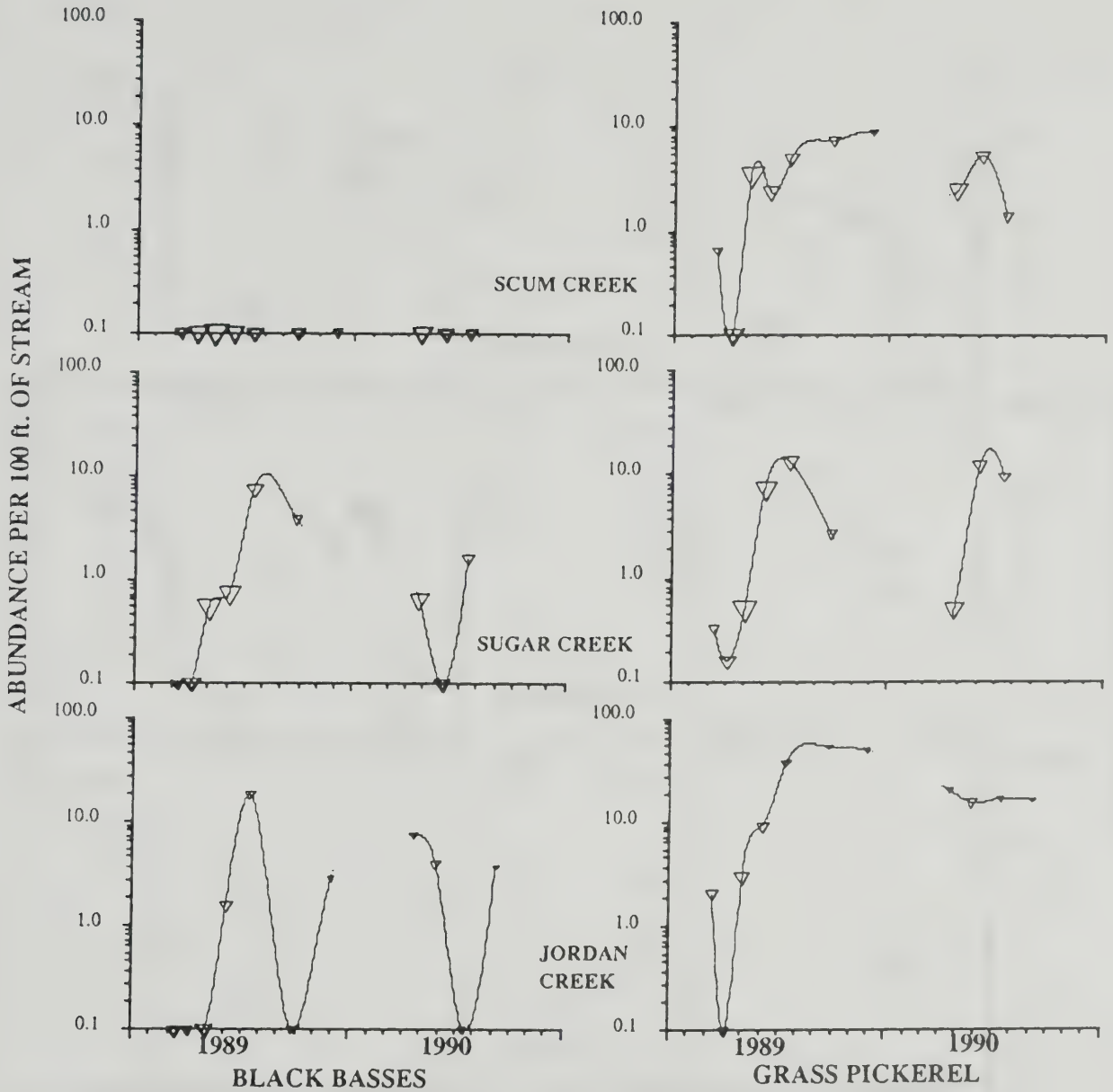


Figure 102.1.11 Abundance density of black basses (left) and grass pickerel (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

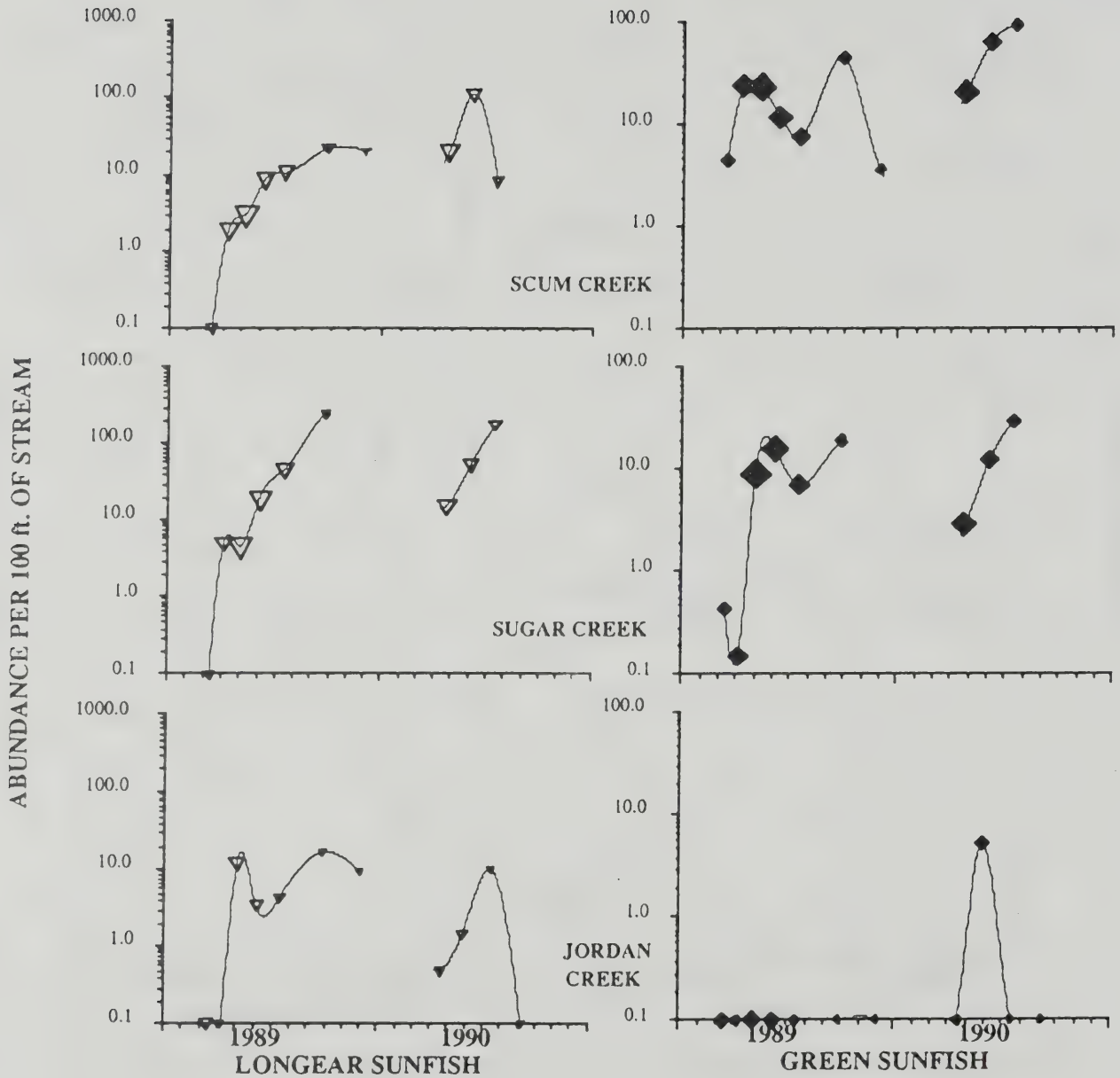


Figure 102.1.12 Abundance density of longear sunfish (left) and green sunfish (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

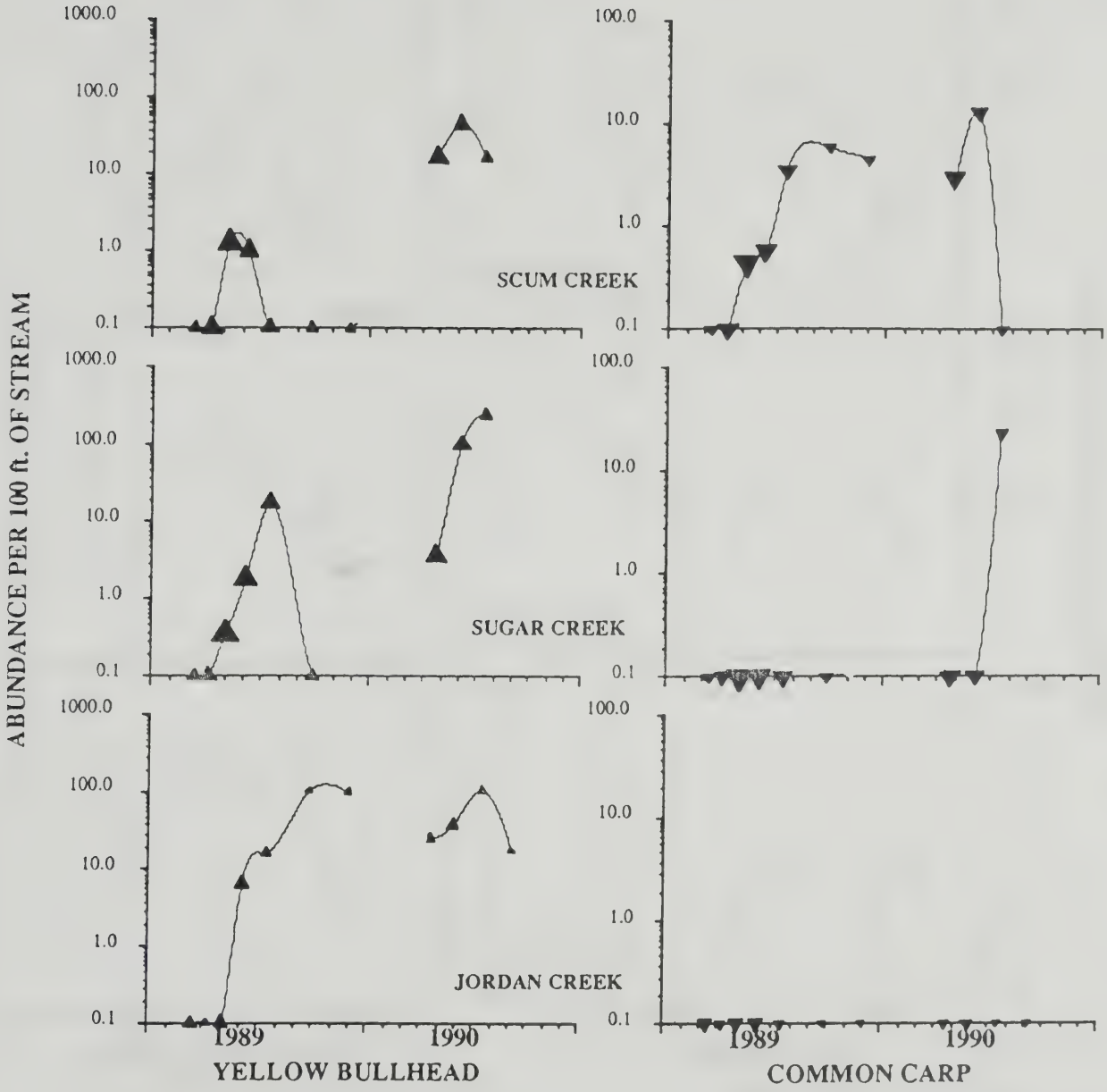


Figure 102.1.13 Abundance density of yellow bullhead (left) and common carp (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

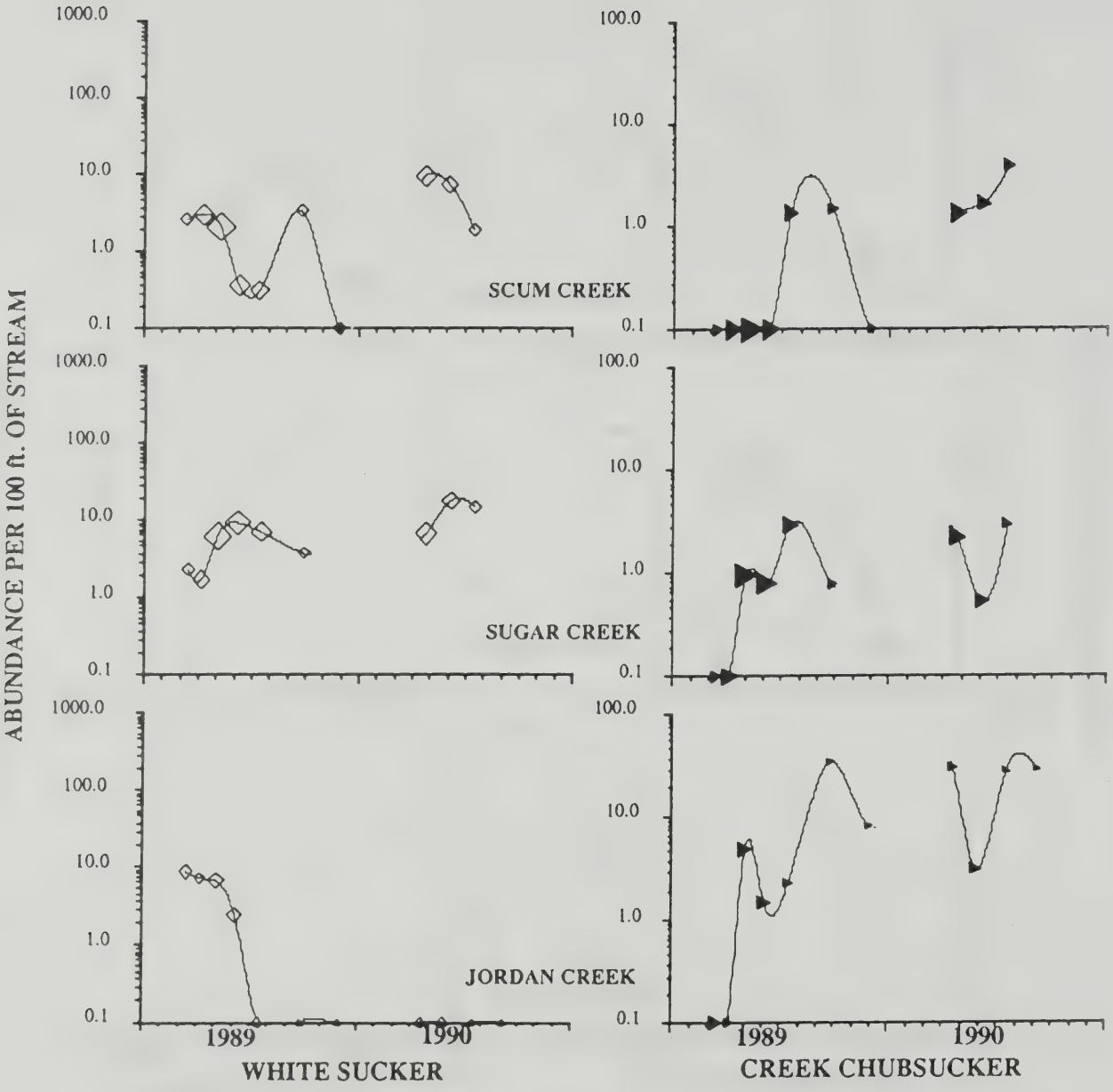


Figure 102.1.14 Abundance density of white sucker (left) and creek chubsucker (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

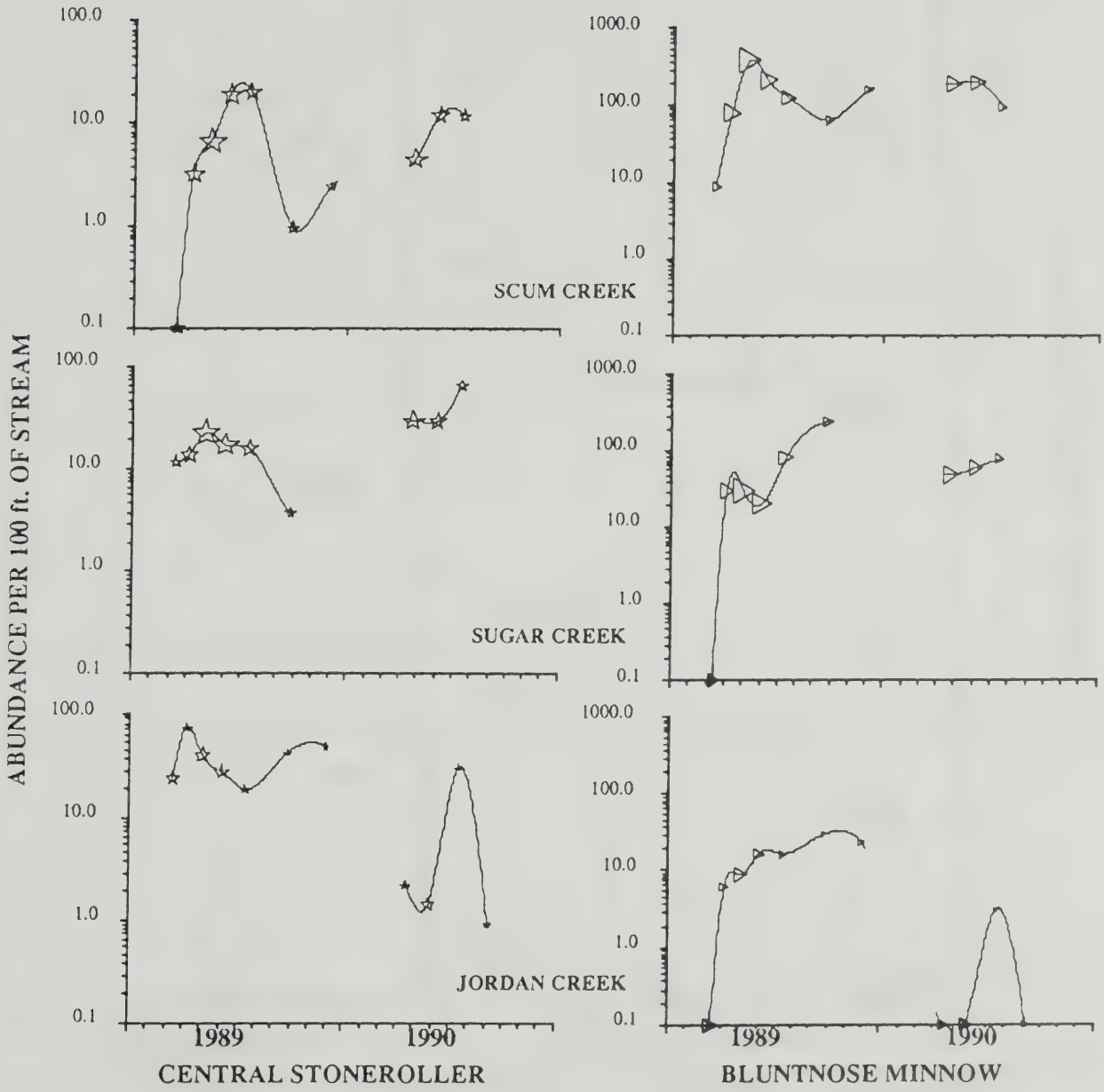


Figure 102.1.15 Abundance density of central stoneroller (left) and bluntnose minnow (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

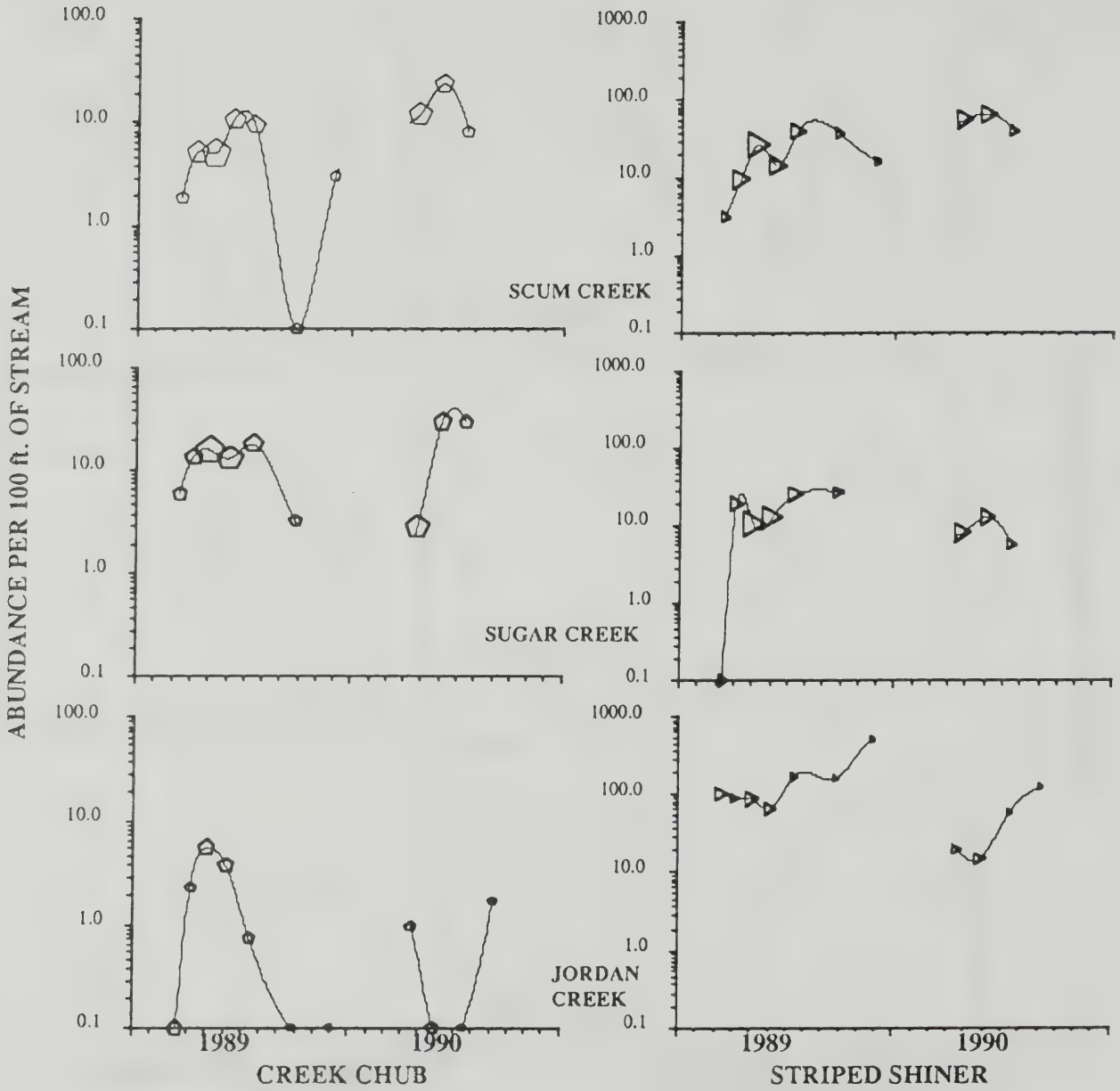


Figure 102.1.16 Abundance density of creek chub (left) and striped shiner (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

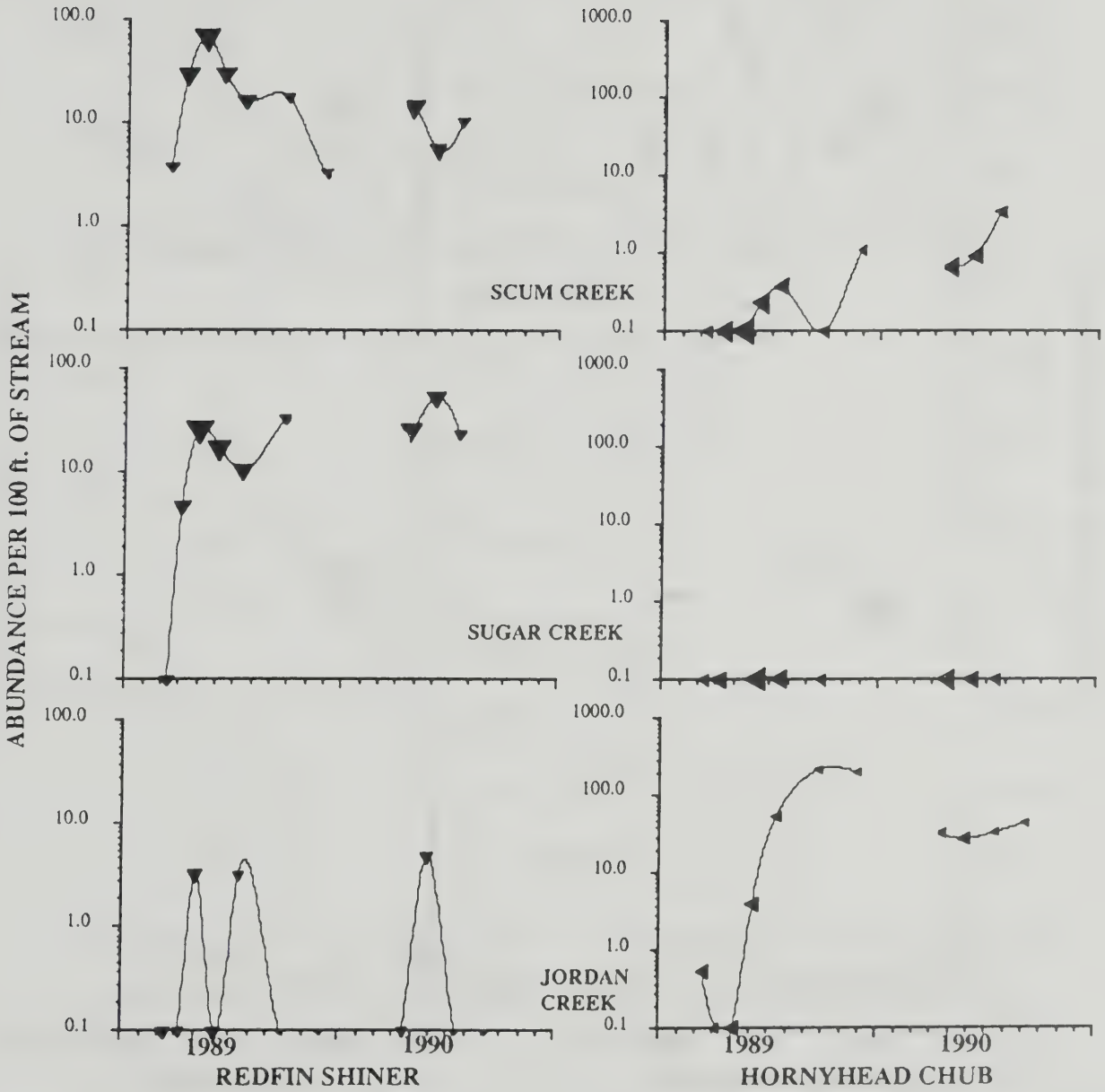


Figure 102.1.17 Abundance density of redfin shiner (left) and hornyhead chub (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

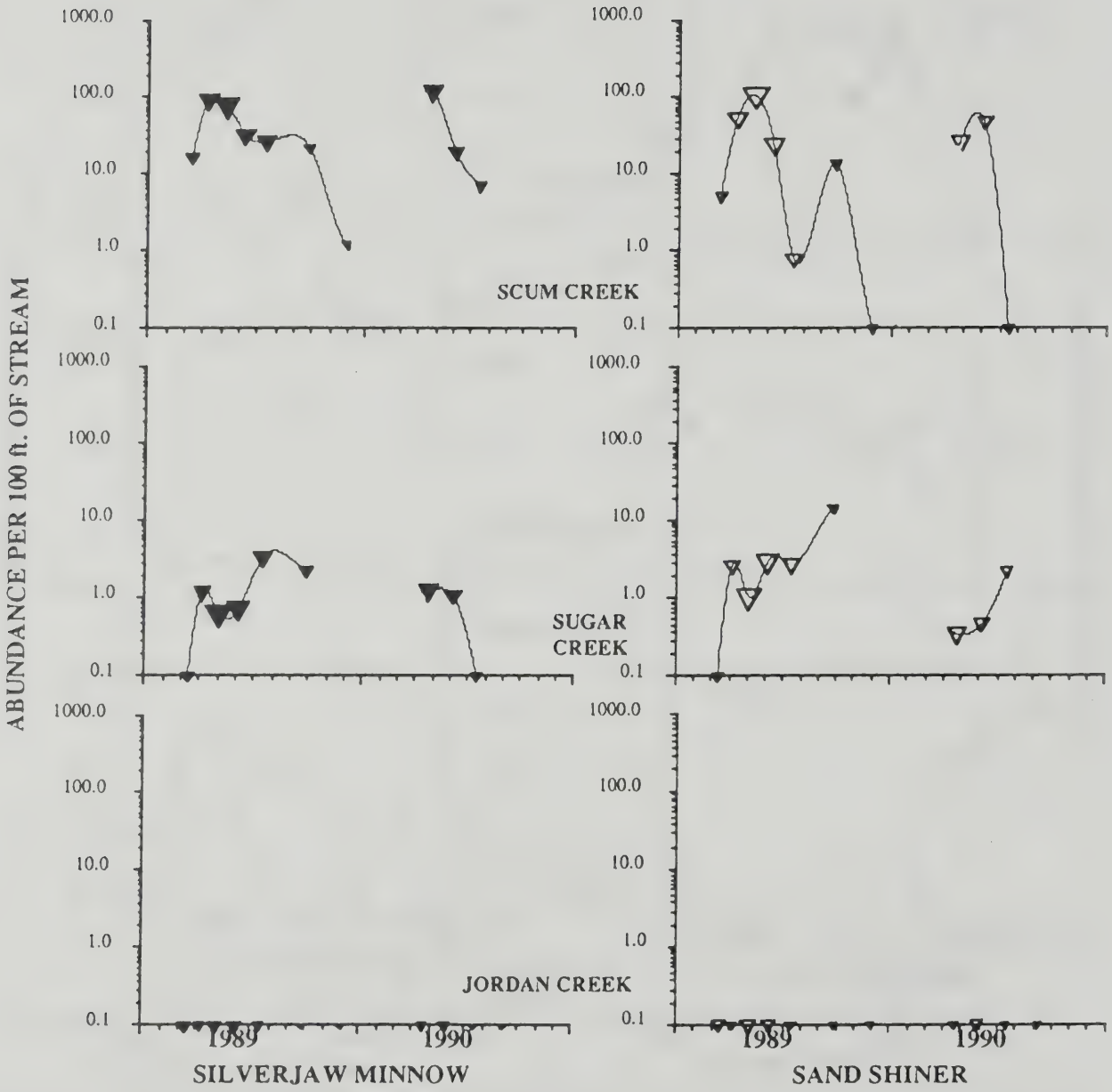


Figure 102.1.18 Abundance density of silverjaw minnow (left) and sand shiner (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

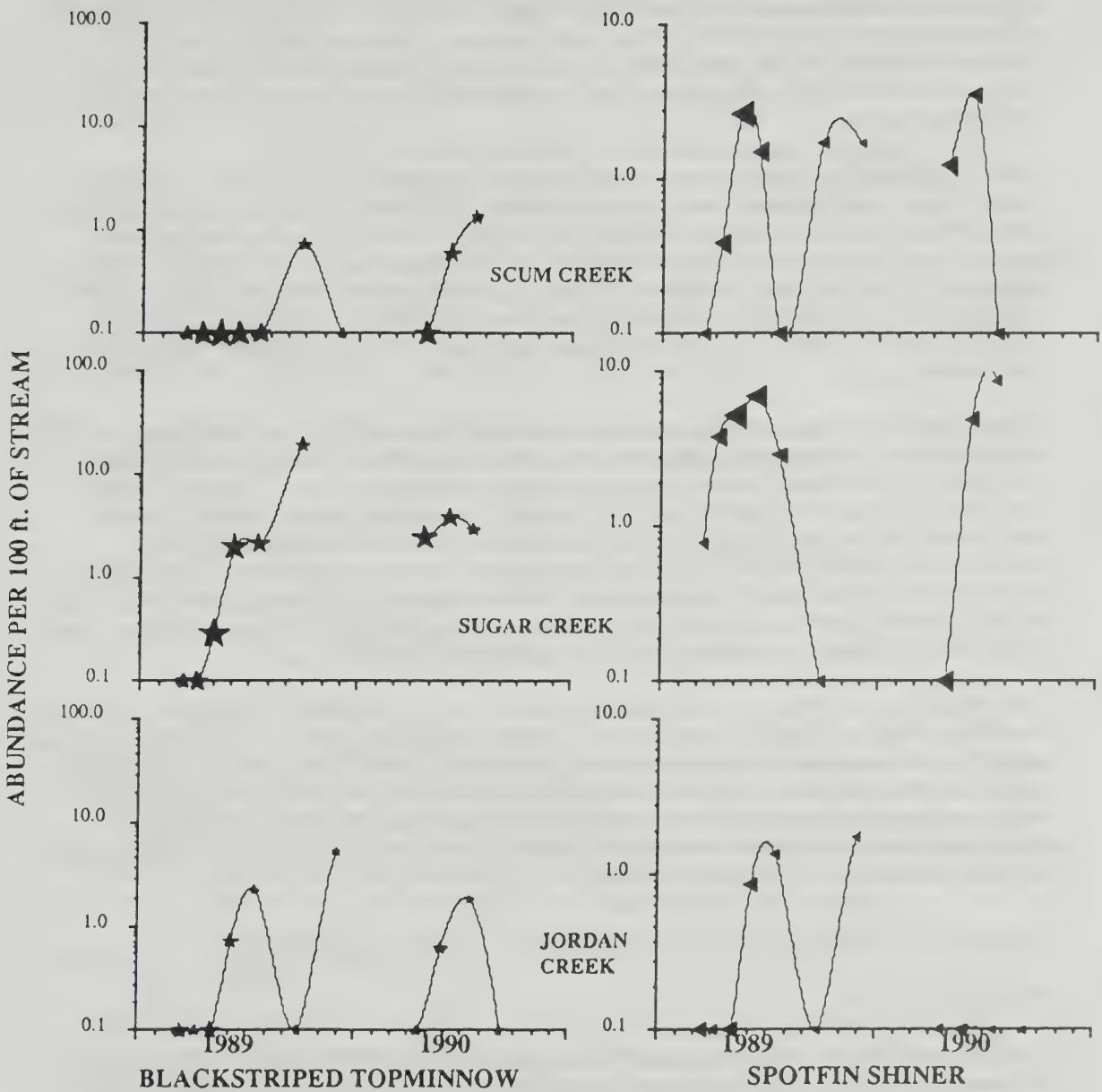


Figure 102.1.19 Abundance density of blackstriped topminnow (left) and spotfin shiner (right); (= numbers of fish per 100 ft. of stream using gear efficiency formula) during two post-drought years in formerly dessicated stretches of three streams. Size of symbols proportional to number of samples averaged in each 5-week period.

species richness during the second post-drought year. Summer richness estimates from Sugar Creek sites between 1985 and 1988 ranged from 11 to 29 species, so the two peaks of 18 species in 1989 and 1990, which were averages of several samples, suggest that recovery according to this metric was rapid. Estimated species richness values based on species richness efficiencies showed similar trends, with values about 20 % higher than the raw values shown.

Peaks in abundance density were attained in April, September, and December 1989 in Scum, Sugar, and Jordan Creek, respectively (Fig. 102.1.10, left side). Corresponding peaks did not show an increase in magnitude in 1990. Peaks in biomass density were attained in about June, July, and November 1989 in Scum, Sugar, and Jordan Creek, respectively (Fig. 102.1.10, right side). Corresponding peaks in 1990 did suggest an increase in magnitude from Scum and Sugar Creek. The fall in biomass and abundance indicated for April-May in Jordan Creek was associated with very high discharges during this period.

Abundance density values for separate species often indicate migrations associated with life history events. For example, the central stoneroller (Fig. 102.1.15) migrates upstream in the spring to spawn and is already moving back downstream by June. The white sucker (Fig. 102.1.14) has a similar but earlier migration. In contrast, more sedentary species such as the longear sunfish (Fig. 102.1.12), immigrate more slowly. Their 1989 movement is probably more of a colonization response to the drought than a typical life history event. An increase in abundance in 1990 is suggested for some species, including longear sunfish, green sunfish, yellow bullhead, hornyhead chub, but many species show no such trend despite the hydrological contrasts between the two years.

This preliminary summary of the data suggests that the fish were able to recover quickly from the drought of 1988. In fact, much of the data does not suggest a colonization process any different from what normally occurs as fish move upstream to spawn and/or disperse from their overwintering pools. It should be stressed that this was a 'pulse' disturbance which had a natural cause, and, most importantly, allowed a return to hydrological conditions which had existed previously. The next section analyzes the overall effect that the low water in 1988 had on the fish of a whole basin.

BASINWIDE EFFECTS OF THE DROUGHT ON FISH QUANTITIES

INTRODUCTION

The final objective of the drought study was to estimate the effect of the 1988 drought on the quantity of fish in a large drainage area that included rivers that did not cease flowing. The 460 mi^2 Salt Fork basin proved ideal for this purpose.

METHODS

Quantitative samples, corrected for gear efficiency (Bayley and Dowling 1990), were obtained during 1987, 1988, 1989, and 1990 throughout the basin (Fig. 102.1.1), which included two of the three desiccated streams analyzed in the previous section.

One could not assume that the biomass or abundance of fish was constant in permanently flowing rivers before, during, or after the 1988 drought. Also, biomass and abundance vary during the growing season, reaching a maximum in late summer-early fall, which is the period when the effects of the drought was most extensive. A model was developed that allowed testing of biomass, abundance, and species richness between years, while

accounting for the effect of the size of each stream segment sampled. This model also allowed the estimation of total biomass in the whole basin and subunits affected by the drought. The model is:

$$BPL = aL^b \quad (1)$$

where BPL = biomass of fish per unit length stream segment
L = length of stream from source to the segment sampled
a, b are fitted constants

Residuals were well-behaved when the linearized version log(BPL) versus log(L) was fit to the data. The linearized version can be used in analyses of covariance (with log(L) as the covariate) to test differences between years and subbasins. A similar model was used for abundance (numbers of fish per segment length substituted for BPL) and richness estimated from the species richness efficiency (RICHNESS = a' + b'log(L)).

In order to estimate total biomass, biomass density per acre of water, and loss during the drought, the model can be integrated over a range of stream lengths:

$$B \text{ (biomass)} = \int BPL\,dL = a\int L^b dL$$

between stream lengths (distances from source) L_2 and L_1.

on integrating,

$$B = a[L_2^{(b+1)} - L_1^{(b+1)}]/(b+1) \quad (2)$$

where $L_2 > L_1$

Providing that the samples are representative of the various sizes and types of streams in the basin and that a reasonable fit to the model is obtained, this model provides a means to estimate biomass in any section or stream network in the basin, and is independent of variation in stream width. However, a similar allometric relationship between stream length to source and stream width corresponding to a particular hydrological season was derived and used to express results as biomass per unit water area for that season.

RESULTS AND DISCUSSION

Analyses were restricted to the period July through September when fish biomass and abundance are at their annual maxima and when the drought effects in 1988 were fairly uniform throughout the basin. The model, (1), and its variants provided virtually identical predictions of biomass and abundance (less darters), and species richness for each of the four years. Differences were not even remotely significant. There was no indication that particular subbasins had more or less biomass or individuals which would have required a stratified analysis.

This comparison excludes smaller streams that were dry during 1988, but predictions of the flowing streams during the July-September period in 1988 were virtually identical to those of the preceding and succeeding years. This indicates that the overall fish biomass and numbers were not concentrating in the permanent water during 1988, although some individual species may have.

Due to the lack of differences observed, the data (88 samples between July and September) were pooled for the four years, and the parameters from the linearized version of the model

were estimated. The model explained 64% of the variance in biomass per unit stream length (BPL) with no outliers, and provided a basis for estimating the fish biomass lost in the desiccated streams during 1988.

Field observations during July through September, 1988 identified desiccated areas, in which a minority of the few higher gradient stream sections contained a few remaining pools, as listed below:

Name of subbasin	Length of longest reach desiccated
Jordan Creek	7.6 miles
Lower Salt Fork	5.7
Upper Salt Fork	7.9
Salt Fork	9.9
Saline Ditch	8.2
Smiths branch	7.5
Stony Creek 1	6.5
Stony Creek 2	6.6

These subbasins were all close to 10,000 acres in drainage area, and had outflowing streams of 13 to 21 feet wide under normal summer conditions. The estimate is conservative, because surface flow often ceased in stream sections downstream of these subbasins. All stream length segments in the basin were measured, using 7.5-minute USGS maps, and allocated to the 1988-desiccated category or the permanent water category. This provided a series of L_1 and L_2 distance-to-source measurements for use in the integrated model (2).

The results are shown in Table 102.1.5. The principal conclusion from this preliminary analysis is that 17% of the normal fish biomass (90 tons) was lost to the Salt Fork basin during the drought of 1988. This gives an idea of the loss that would be sustained if continuous water extraction during the low summer months were to become widespread. Currently there is no legislation to prevent this process.

In this case history of the Salt Fork basin, the drought was natural, and the biomass in the upper reaches returned to normal levels in 1989 and 1990, despite the fact that a 'semi-drought' occurred in 1989. This large-scale analysis supports the individual stream colonization results shown in the previous section, and indicates that the fish species of this basin are well-adapted to temporary disturbances in surface flow.

Table 102.1.5 Estimated total biomass of fish (less darters) in the Salt Fork basin under normal conditions, based on 88 efficiency-corrected samples in July-September from 1987-90.

Network	Total miles of stream	Fish biomass (t)	% of total biomass	biomass per unit area of water (lb/acre)
Whole basin	453	90.0	100	241
Streams permanent in 1988	91	74.6	83	285
Streams desiccated in 1988	361	15.4	17	154

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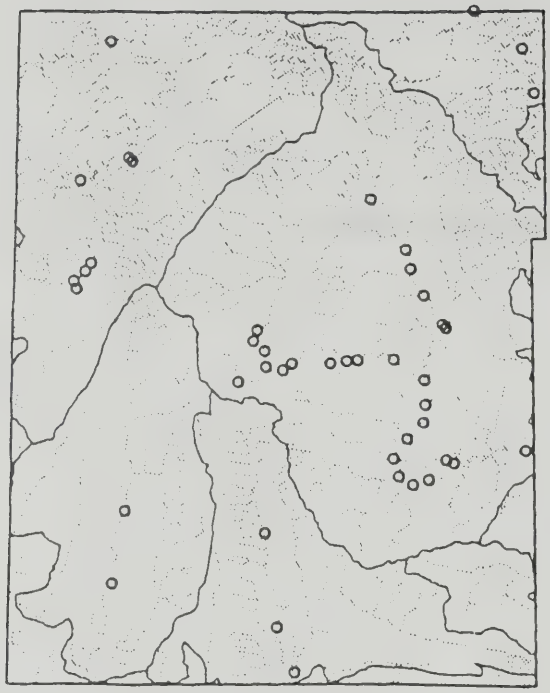
APPENDIX A-1. Species List

Table A.1 FAS codes, scientific names, and common names of fish species used in this report

FAS Code	Scientific Name	Common Name
BAD	Etheostoma zonale	Banded Darter
BCF	Ictalurus furcatus	Blue Catfish
BGB	Ictiobus cyprinellus	Bigmouth Buffalo
BGC	Hybopsis amblops	Bigeye Chub
BGS	Notropis boops	Bigeye Shiner
BKB	Ictiobus niger	Black Buffalo
BLB	Ameiurus melas	Black Bullhead
BLC	Pomoxis nigromaculatus	Black Crappie
BLD	Percina maculata	Blackside Darter
BLG	Lepomis macrochirus	Bluegill
BLR	Moxostoma duquesnei	Black redhorse
BLS	Pimephales notatus	Bluntnose Minnow
BLT	Fundulus notatus	Blackstripe Topminnow
BMS	Hybopsis dorsalis	Bigmouth Shiner
BNS	Notropis heterolepis	Blacknose Shiner
BRB	Ameiurus nebulosus	Brown Bullhead
BRM	Noturus miurus	Brindled Madtom
BRS	Labidesthes sicculus	Brook Silverside
BUD	Etheostoma chlorosomum	Bluntnose Darter
BUM	Pimephales vigilax	Bullhead Minnow
CAP	Cyprinus carpio	Common Carp
CAR	Carpiodes spp.	Carpsucker spp.
CCF	Ictalurus punctatus	Channel Catfish
CCS	Erimyzon oblongus	Creek Chubsucker
COS	Campostoma anomalum	Central Stoneroller
CRC	Semotilus atromaculatus	Creek Chub
DUD	Percina sciera	Dusky Darter
EMS	Notropis atherinoides	Emerald Shiner
ESD	Ammocrypta pellucida	Eastern Sand Darter
FAD	Etheostoma flabellare	Fantail Darter
FCF	Pylodictis olivaris	Flathead Catfish
FHM	Pimephales promelas	Fathead Minnow
FRD	Aplodinotus grunniens	Freshwater Drum
FRM	Noturus nocturnus	Freckled Madtom
GOR	Moxostoma erythrurum	Golden Redhorse
GOS	Notemigonus crysoleucas	Golden Shiner
GRD	Etheostoma blennioides	Greenside Darter
GRP	Esox americanus	Grass Pickerel
GSF	Lepomis cyanellus	Green Sunfish
GZS	Dorosoma cepedianum	Gizzard Shad
HFC	Carpoides velifer	Highfin Carpsucker
HOC	Nocomis biguttatus	Hornyhead Chub
HTS	Nocomis biguttatus X Notropis chrysocephalus	Hornyhead X Striped Shiner
JOD	Etheostoma nigrum	Johnny Darter
LGH	Lepomis cyanellus X L. megalotis	Green X Longear Sunfish
LMB	Micropterus salmoides	Largemouth Bass
LNS	Catostomus catostomus	Longnose Sucker
LOG	Lepisosteus osseus	Longnose Gar

LOP	Percina caprodes	Logperch
LOS	Lepomis megalotis	Longear Sunfish
LSS	Campostoma oligolepis	Largescale Stoneroller
MMS	Notropis volucellus	Mimic Shiner
MOF	Gambusia affinis	Mosquitofish
MOO	Hiodon tergisus	Mooneye
MOX	Moxostoma spp.	Redhorse spp.
MUD	Etheostoma asprigene	Mud Darter
NHS	Hypentelium nigriacans	Northern Hogsucker
NSS	Pungitius pungitius	Ninespine Stickleback
ORD	Etheostoma spectabilis	Orangethroat Darter
ORS	Lepomis humilis	Orangespotted Sunfish
OWD	Etheostoma exile	Iowa Darter
PLS	Hybopsis amnis	Pallid Shiner
PRP	Aphredoderus sayanus	Pirate Perch
PUD	Lepomis gibbosus	Pumpkinseed
PUM	Opsopoeodus emiliae (Notropis emiliae)	Pugnose Minnow
RAD	Etheostoma caeruleum	Rainbow Darter
RBS	Notropis fumeus	Ribbon Shiner
RDS	Lythrurus umbratilus	Redfin Shiner
RES	Cyprinella lutrensis	Red Shiner
RFS	Cyprinella lutrensis X C. spiloptera	Red X Spotfin Shiner
ROB	Ambloplites rupestris	Rock Bass
RSF	Lepomis microlophus	Redear Sunfish
RVC	Carpiodes carpio	River Carpsucker
RVS	Notropis blennius	River Shiner
RYS	Notropis rubellus	Rosyface Shiner
SAS	Notropis ludibundus	Sand Shiner
SDS	Minytrema melanops	Spotted sucker
SES	Notropis whipplei	Steelcolor Shiner
SFS	Cyprinella spiloptera	Spotfin Shiner
SHD	Percina phoxocephala	Slenderhead Darter
SHG	Lepisosteus platostomus	Shortnose Gar
SHR	Moxostoma macrolepidotum	Shorthead Redhorse
SJM	Ericymba buccata	Silverjaw Minnow
SLD	Etheostoma gracile	Slough Darter
SLM	Noturus exilis	Slender Madtom
SMB	Micropterus dolomieui	Smallmouth Bass
SPB	Micropterus punctulatus	Spotted Bass
SPC	Extrarius aestivalis	Speckled Chub
STC	Noturus flavus	Stonecat
STS	Luxilus chrysocephalus	Striped Shiner
SUM	Phenacobius mirabilis	Suckermouth Minnow
SVC	Macrhybopsis storeriana	Silver Chub
SVM	Hybognathus nuchalis	Silvery Minnow
SVR	Moxostoma anisurum	Silver Redhorse
TPM	Noturus gyrinus	Tadpole Madtom
ULL	Carpoides cyprinus	Quillback
WAM	Lepomis gulosus	Warmouth
WHB	Morone chrysops	White Bass
WHC	Pomoxis annularis	White Crappie
WHS	Catostomus commersoni	White Sucker
YEB	Ameiurus natalis	Yellow Bullhead

APPENDIX A-2. Geographic Distribution Maps for Selected Fish Species



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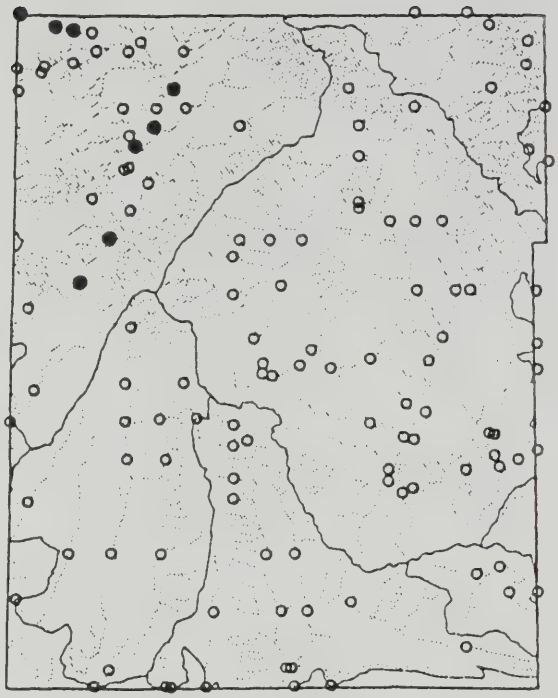

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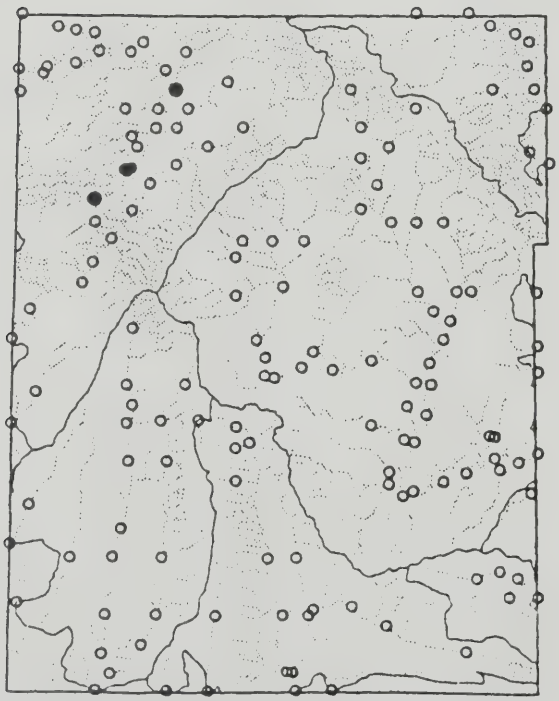

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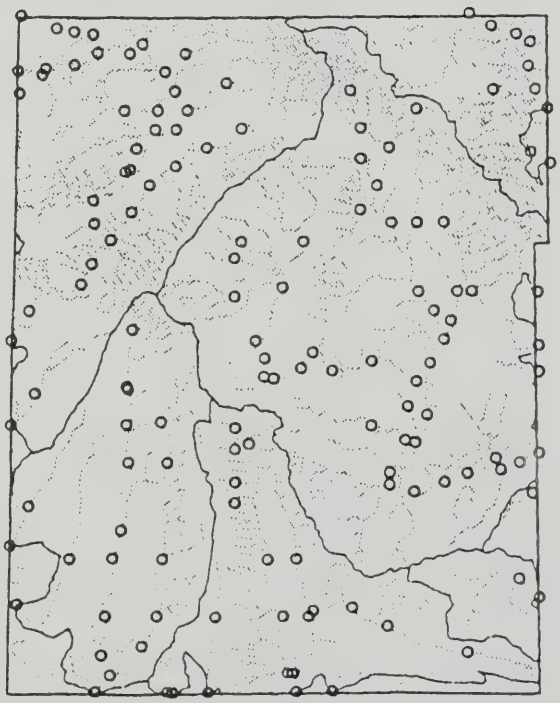


PRESENT STUDY

Fig A1. Closed circle -Presence, Open circle -absence of *Etheostoma zonale* Banded darter (BAD) in Champaign County survey.

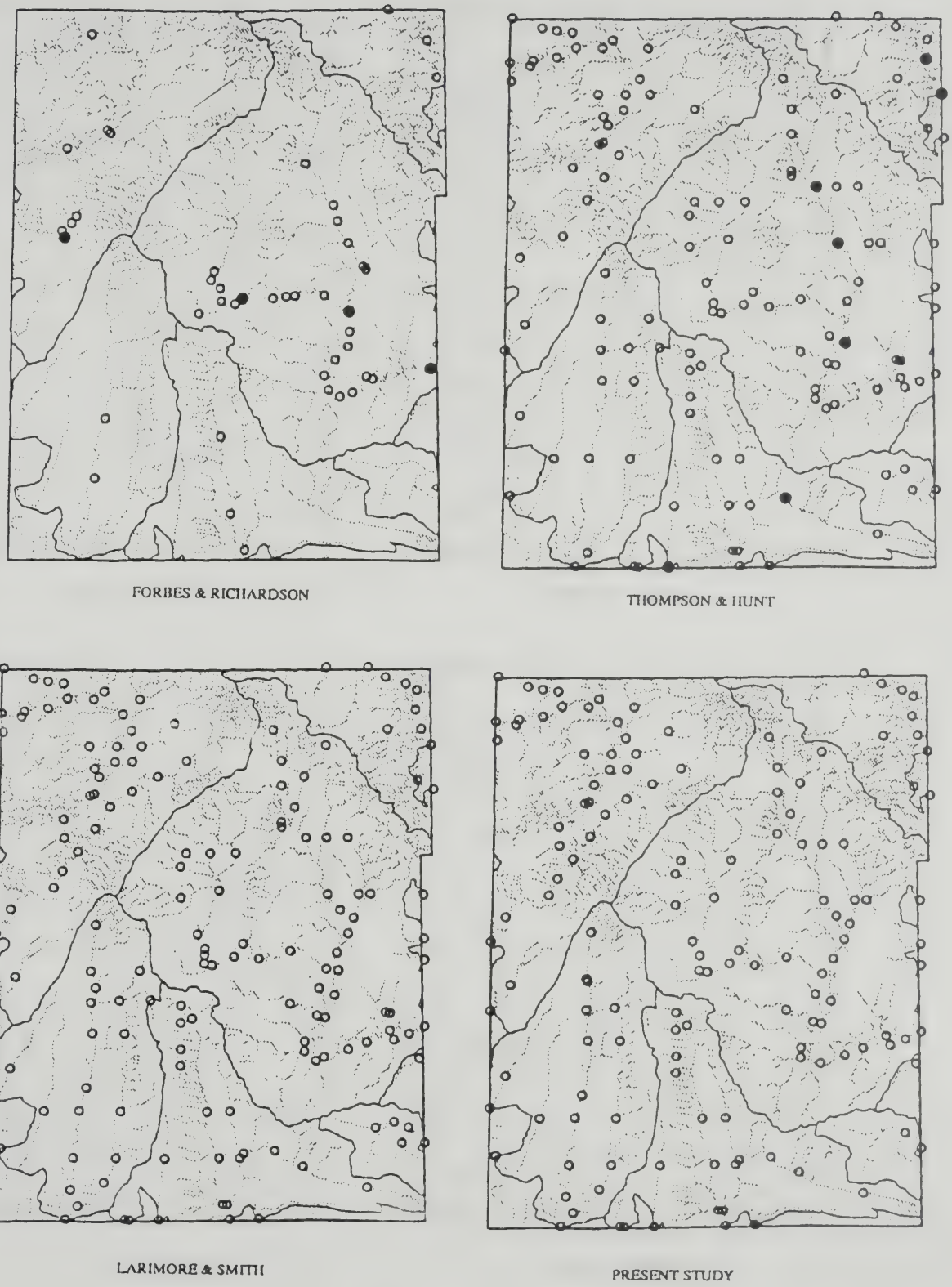


Fig A2. Closed circle -Presence, Open circle -absence of *Hybopsis amblops* Bigeye chub (BGC) in Champaign County survey.

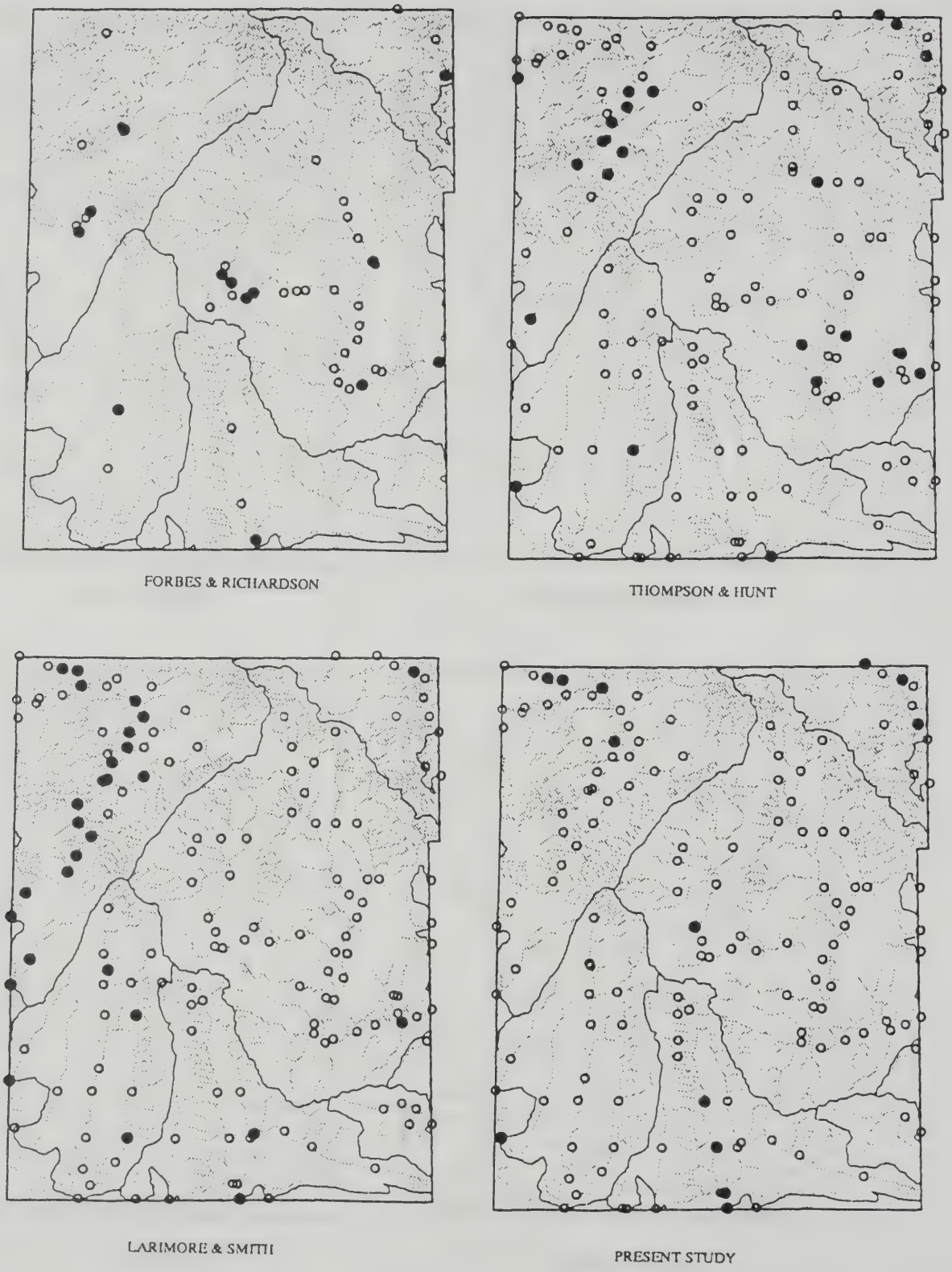


Fig A5. Closed circle -Presence, Open circle -absence of *Percina maculata* Blackside darter (BLD) in Champaign County survey.

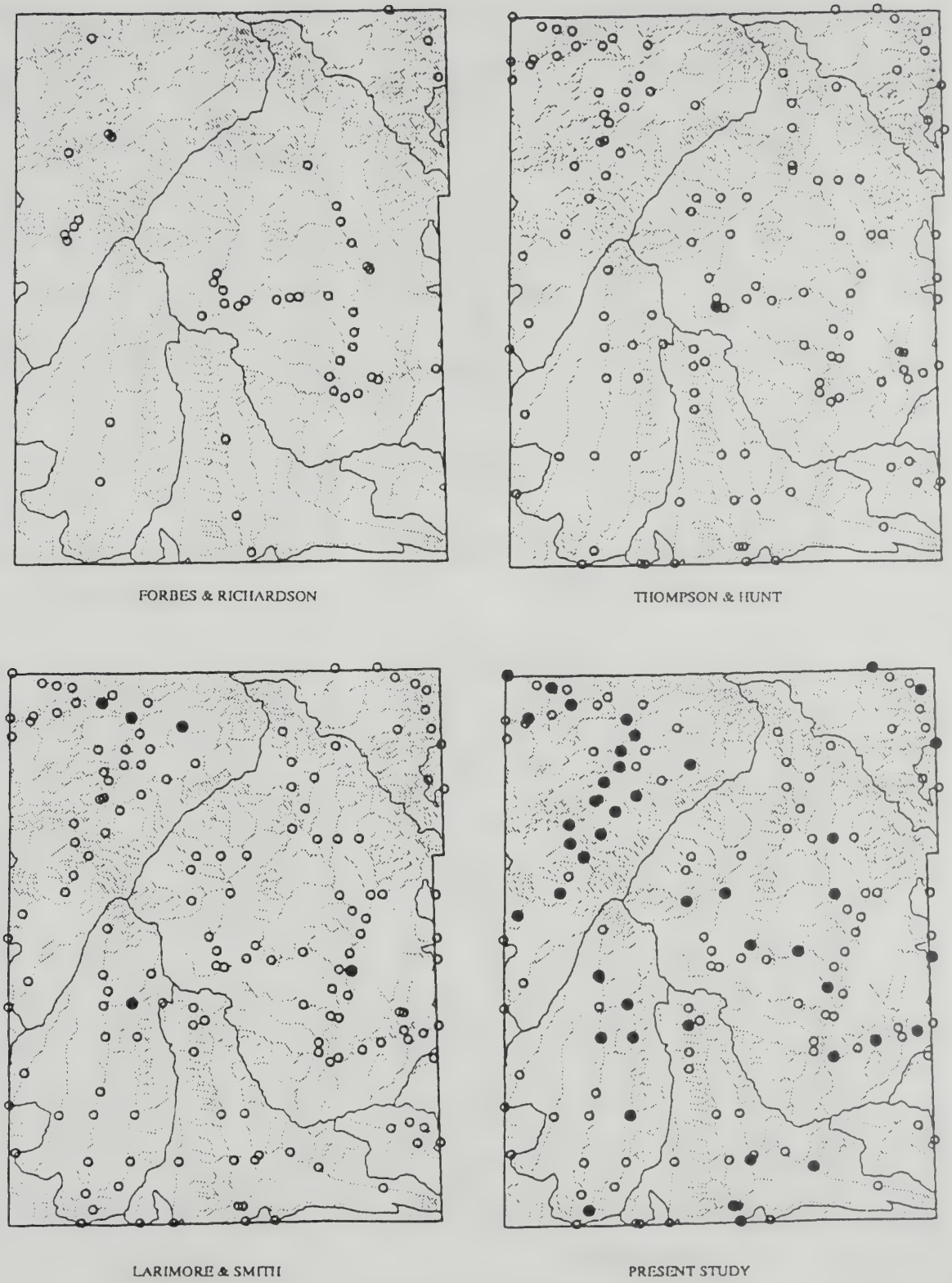


Fig A6. Closed circle -Presence, Open circle -absence of *Lepomis macrochirus* Bluegill (BLG) in Champaign County survey.

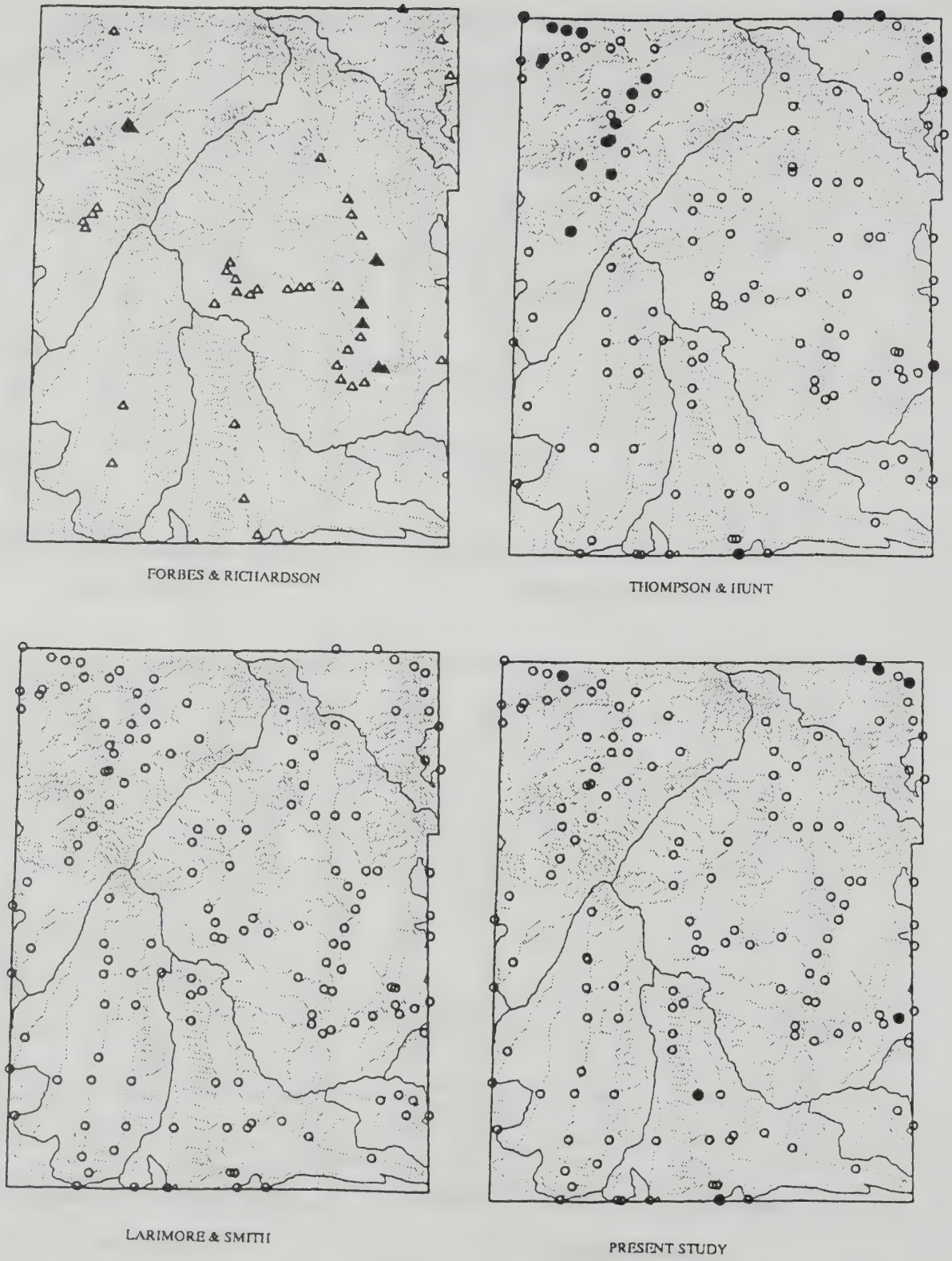
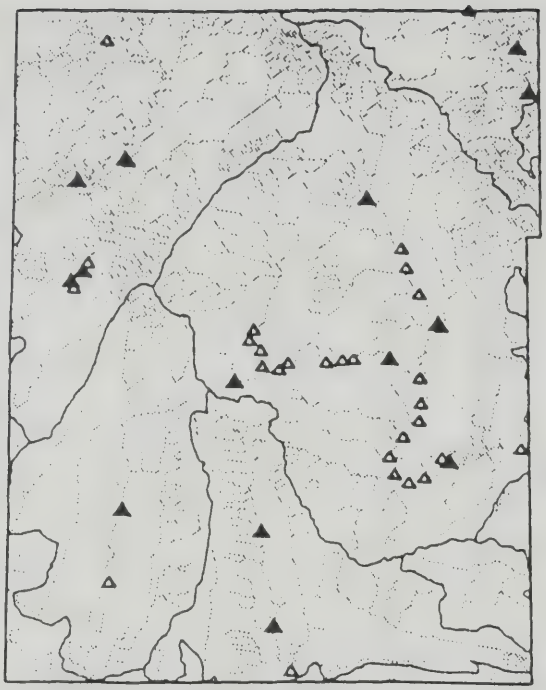


Fig A7. Closed circle -Presence, Open circle -absence of *Moxostoma duquesnei* Black redhorse (BLR) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Black redhorse and Golden redhorse (BLR/GOR)

Fig A8. Closed circle -Presence, Open circle -absence of *Pimephales notatus* Bluntnose minnow (BLS) in Champaign County survey.



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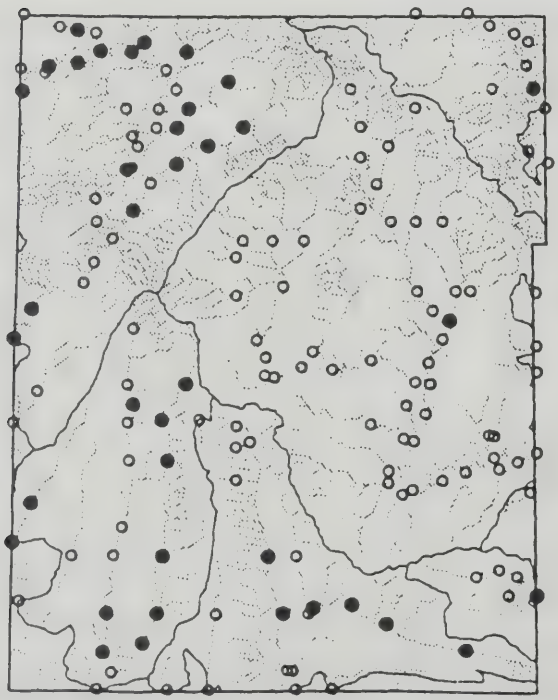

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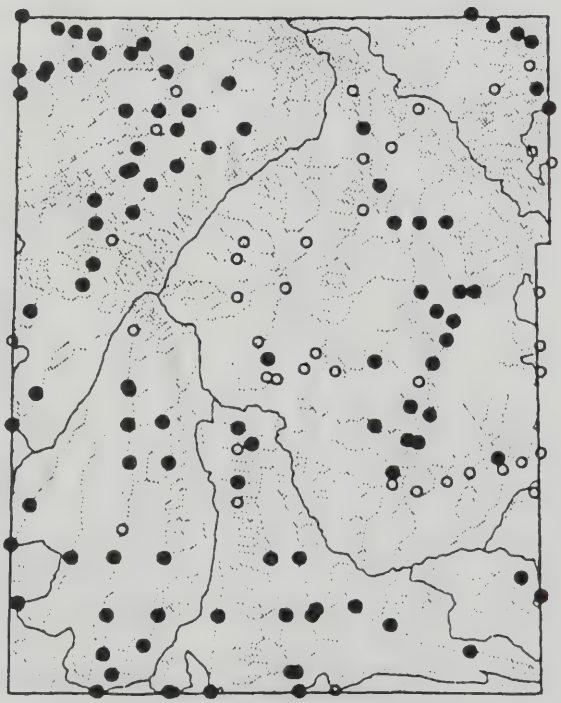


PRESENT STUDY

Fig A9. Closed circle -Presence, Open circle -absence of *Fundulus notatus* Blackstripe topminnow (BLT) in Champaign County survey. Closed triangle -Presence, Open triangle -Absence of Blackstripe topminnow and Blackspotted topminnow (BLT/BST)

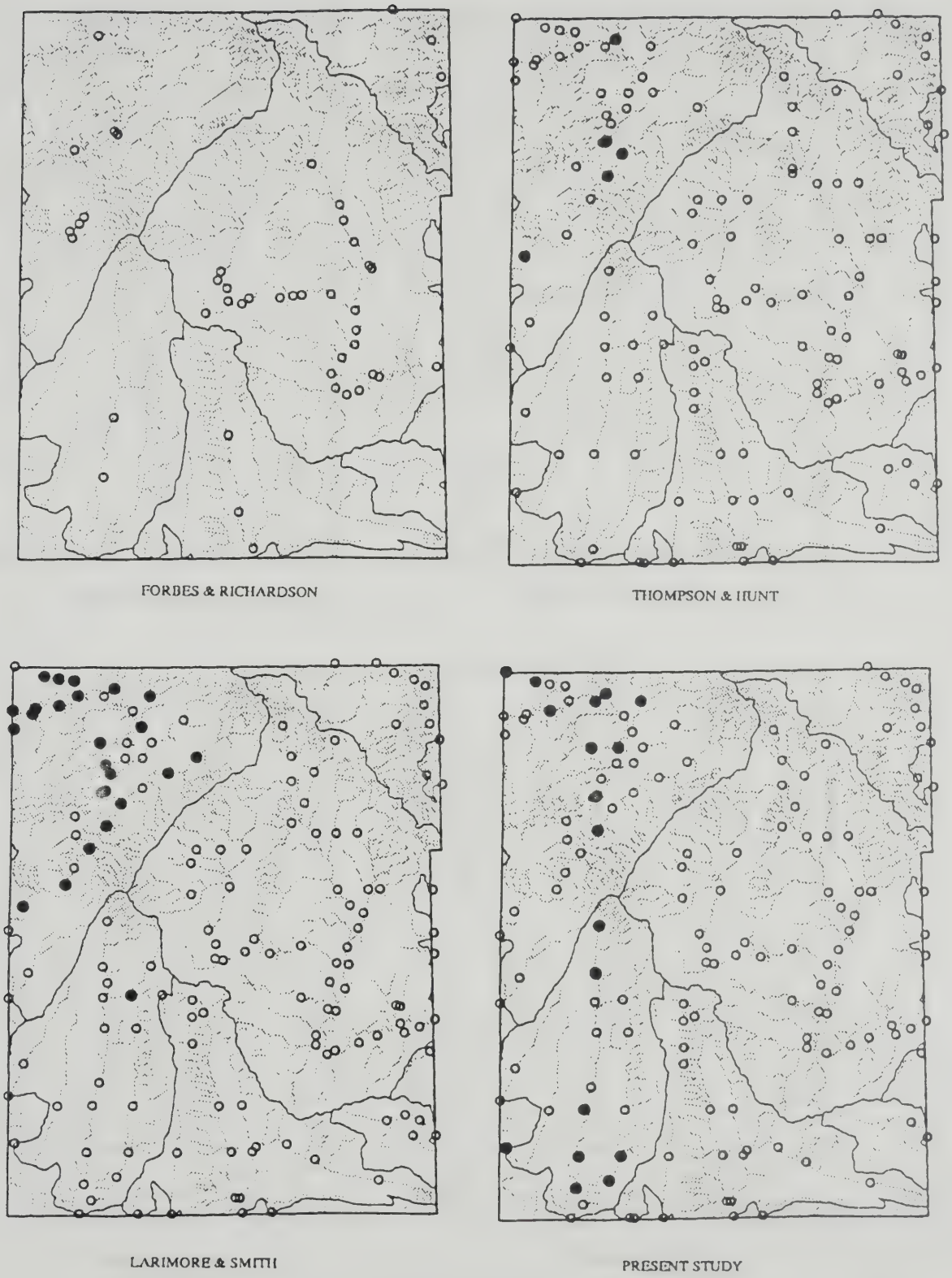


Fig A10. Closed circle -Presence, Open circle -absence of *Hybopsis dorsalis* Bigmouth shiner (BMS) in Champaign County survey.

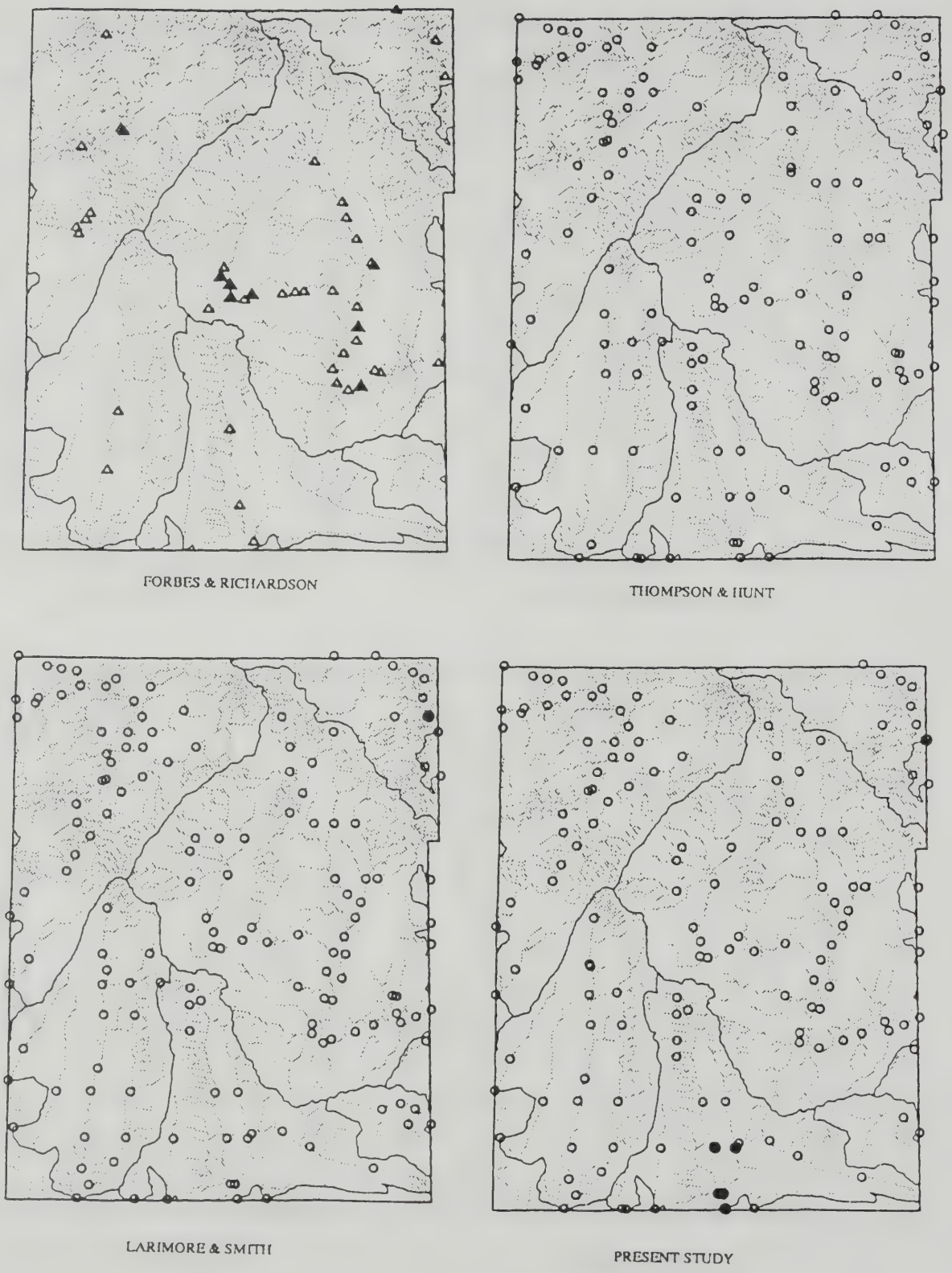
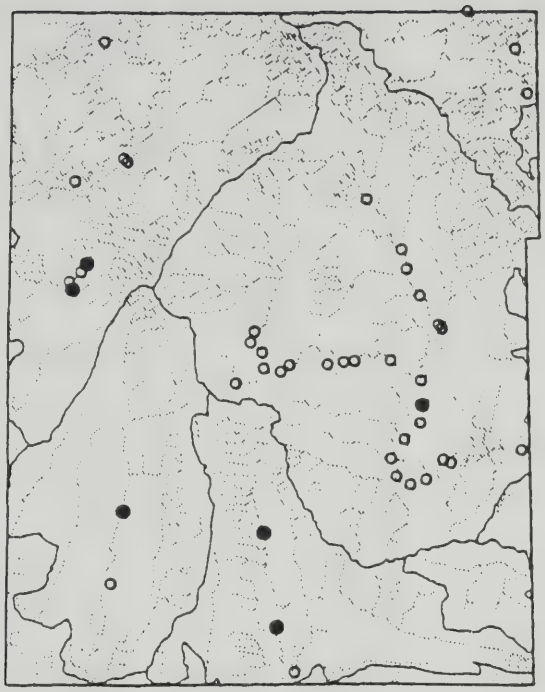


Fig A11. Closed circle -Presence, Open circle -absence of *Noturus miurus* Brindled madtom (BRM) in Champaign County survey. Closed triangle -Presence, Open triangle -absence of Brindled madtom and Mountain madtom (BRM/MOM)



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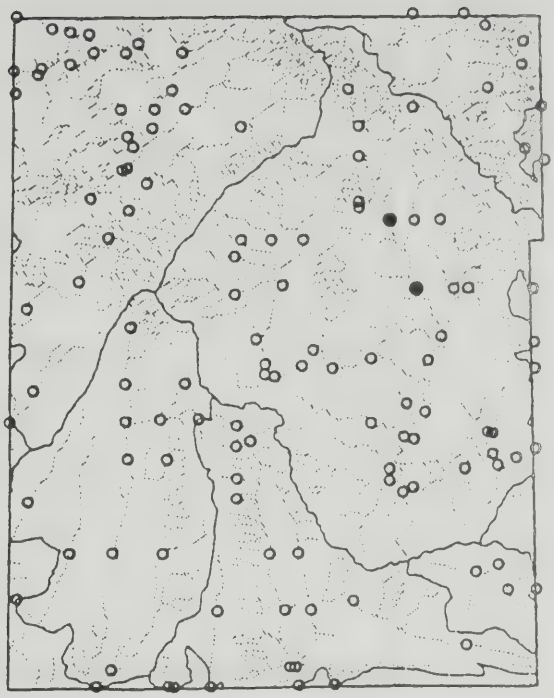

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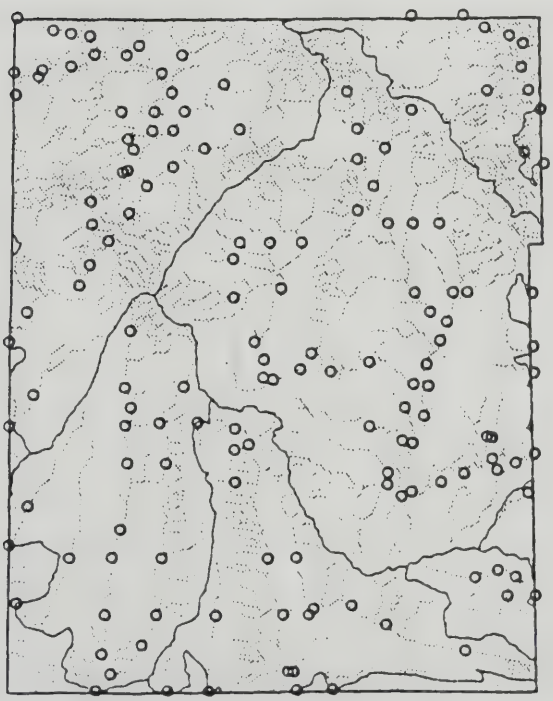

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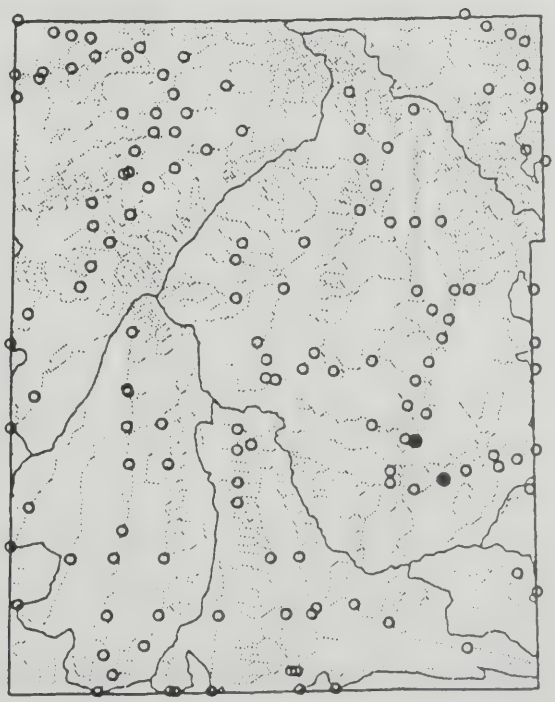
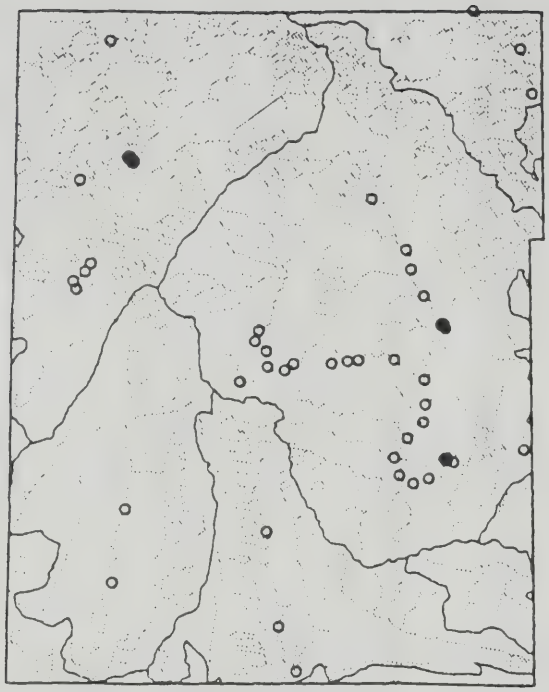


PRESENT STUDY

Fig A12. Closed circle -Presence, Open circle -absence of *Labidesthes sicculus* Brook silverside (BRS) in Champaign County survey.



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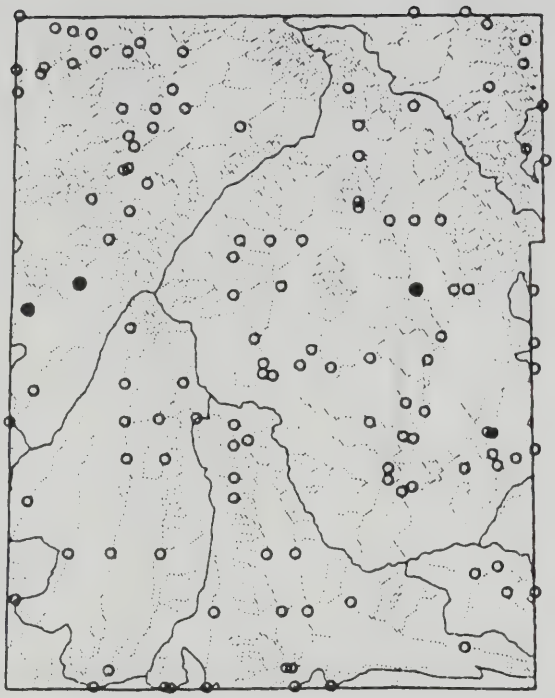

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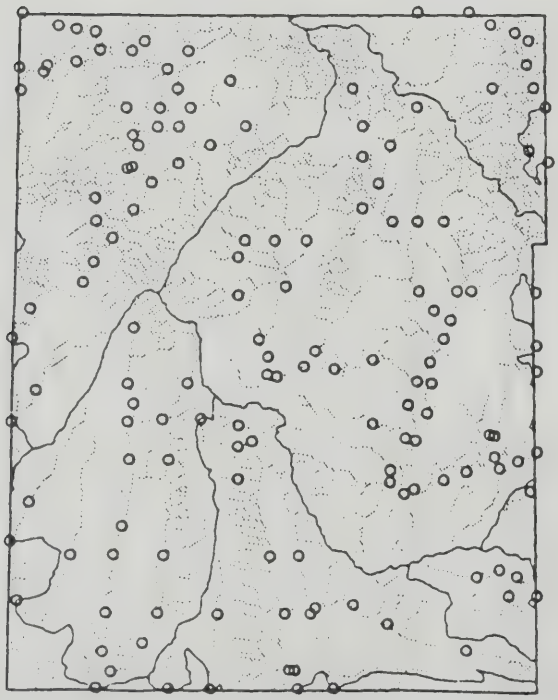

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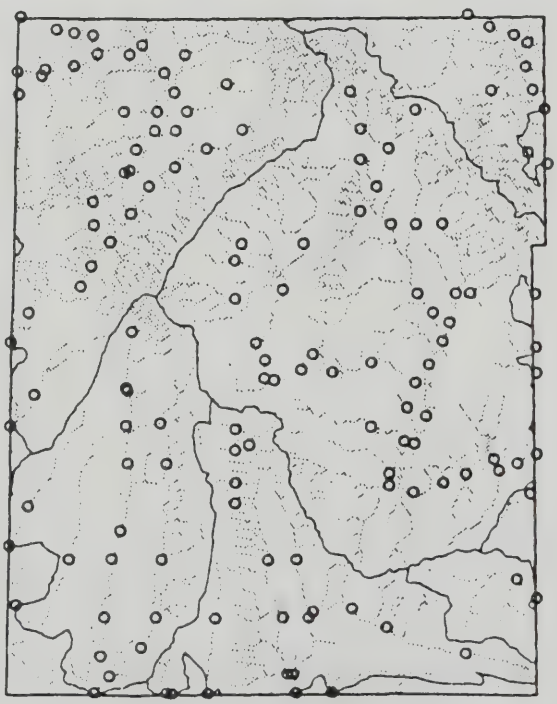


PRESENT STUDY

Fig A13. Closed circle -Presence, Open circle -absence of *Pimephales vigilax* Bullhead minnow (BUM) in Champaign County survey.

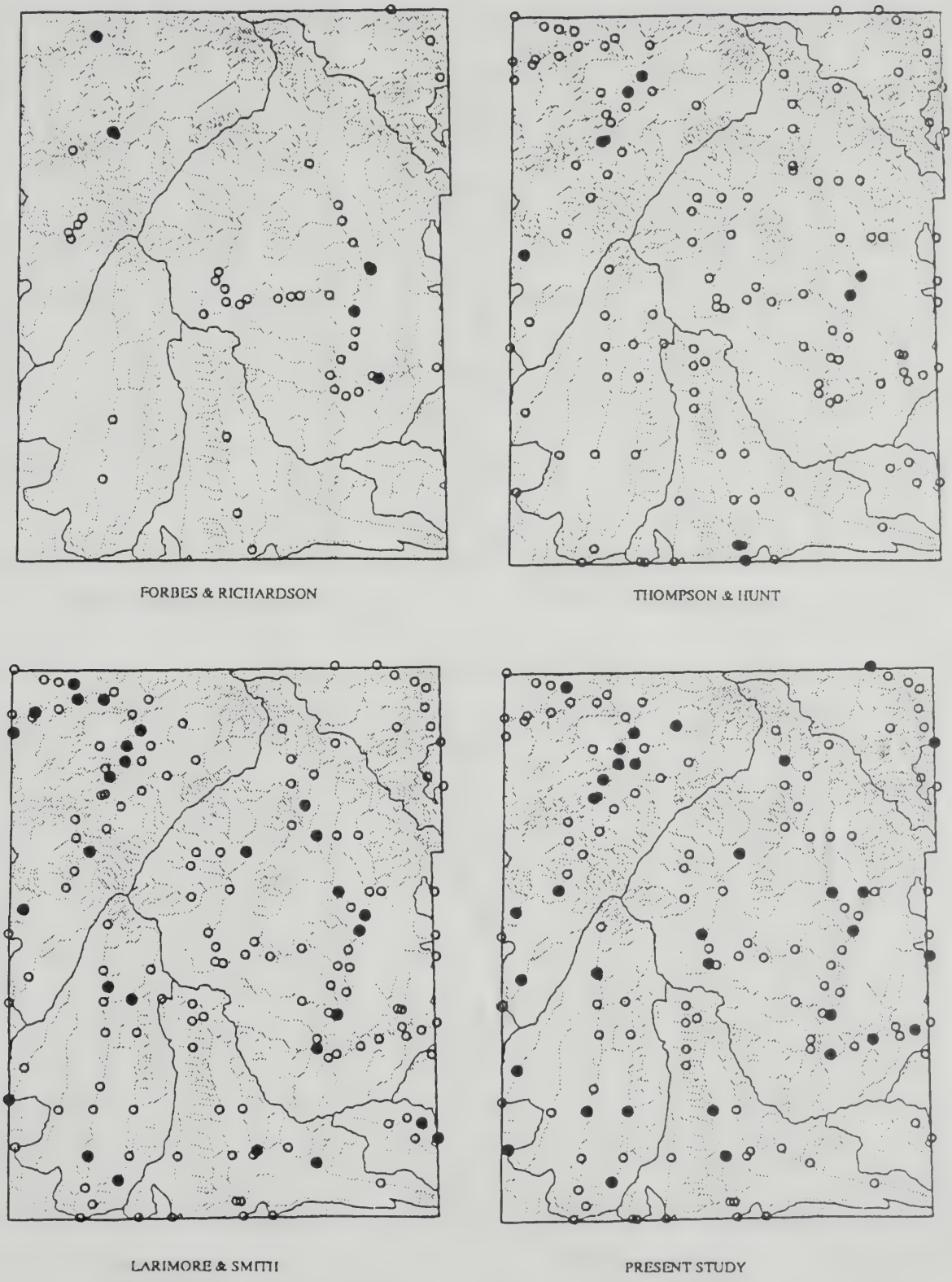


Fig A14. Closed circle -Presence, Open circle -absence of *Cyprinus carpio* Carp (CAP) in Champaign County survey.

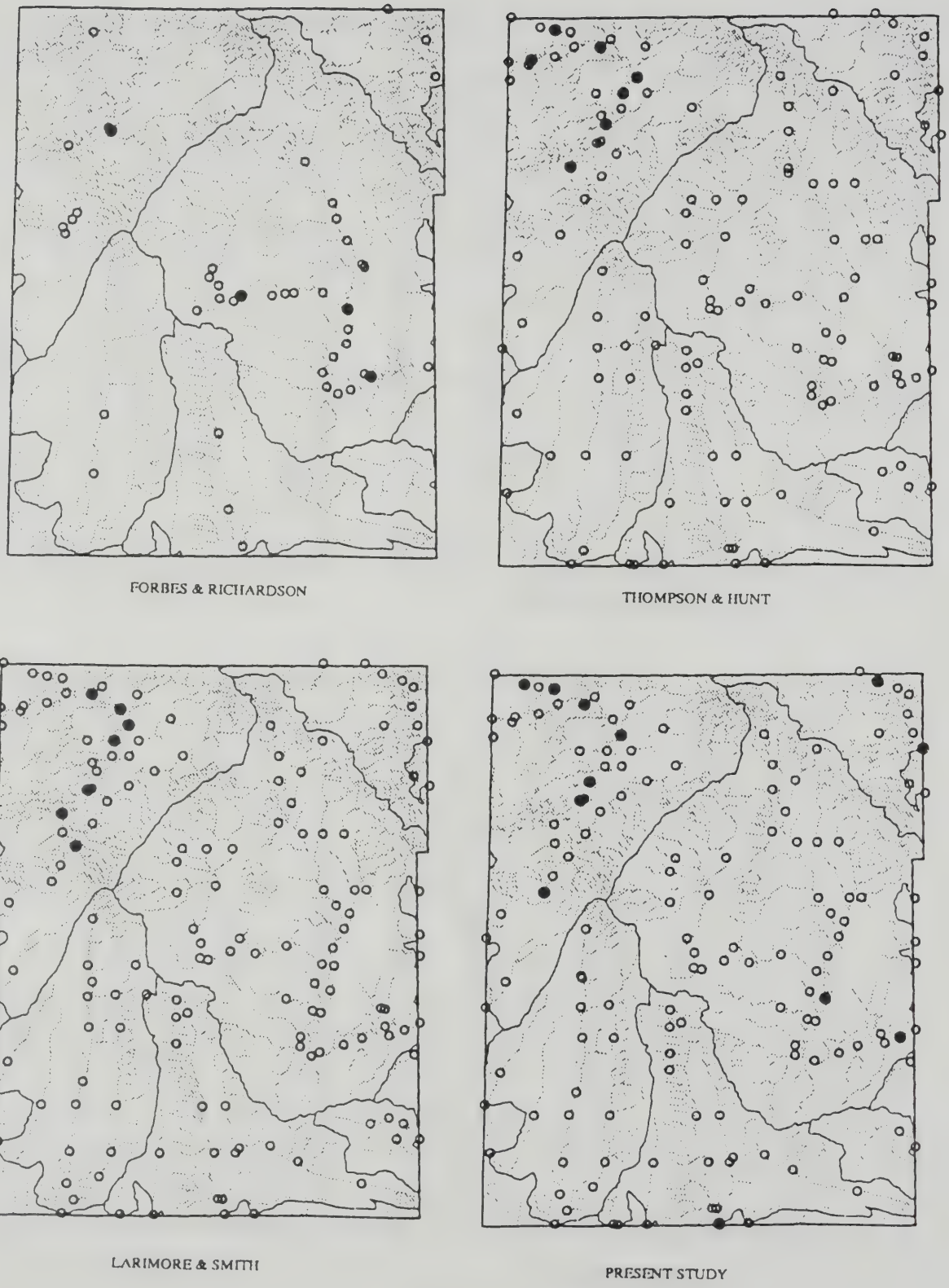
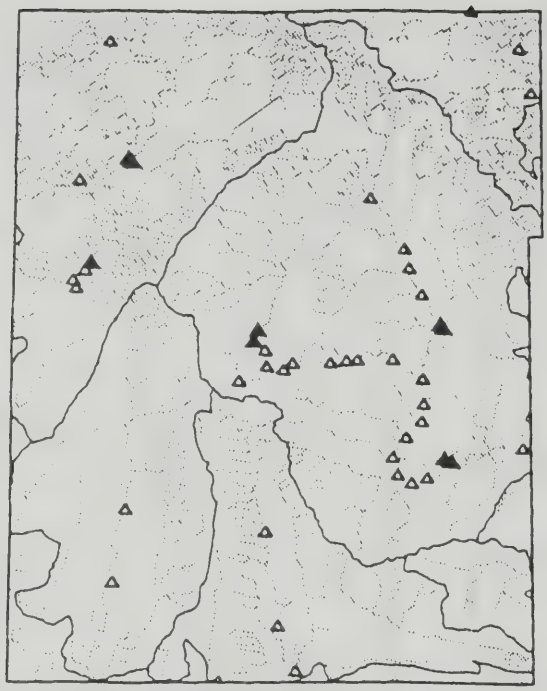


Fig A15. Closed circle -Presence, Open circle -absence of *Ictalurus punctatus* Channel catfish (CCF) in Champaign County survey.

Fig A16. Closed circle -Presence, Open circle -absence of *Erimyzon oblongus* Creek chubsucker (CCS) in Champaign County survey. Closed triangle -Presence, Open triangle -absence of Creek chubsucker and Lake chubsucker (CCS/LCS)



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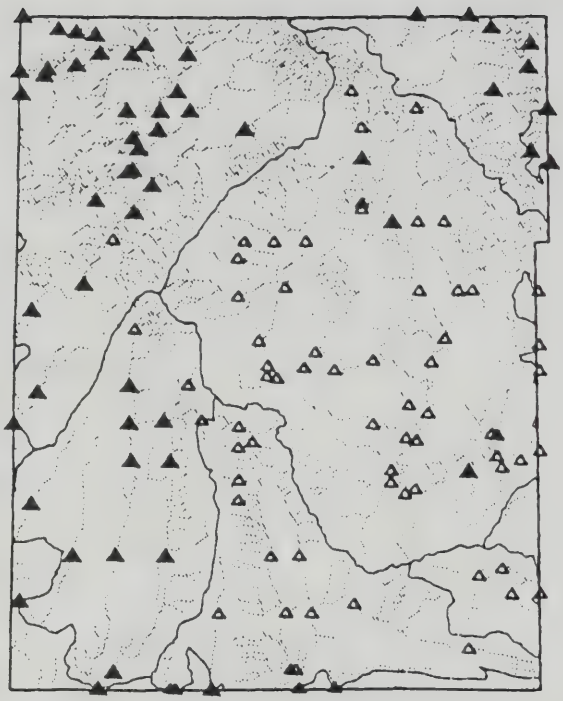

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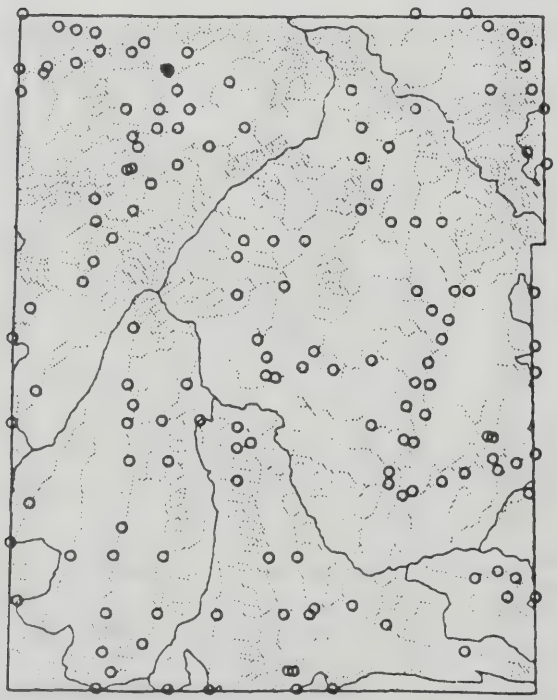
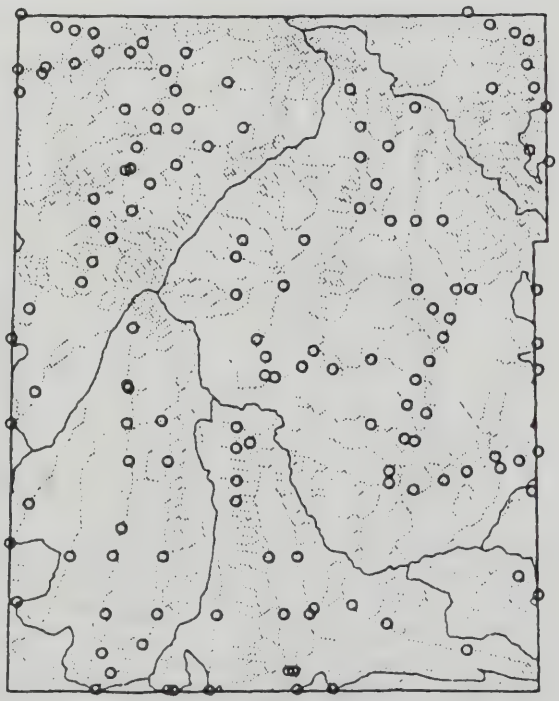
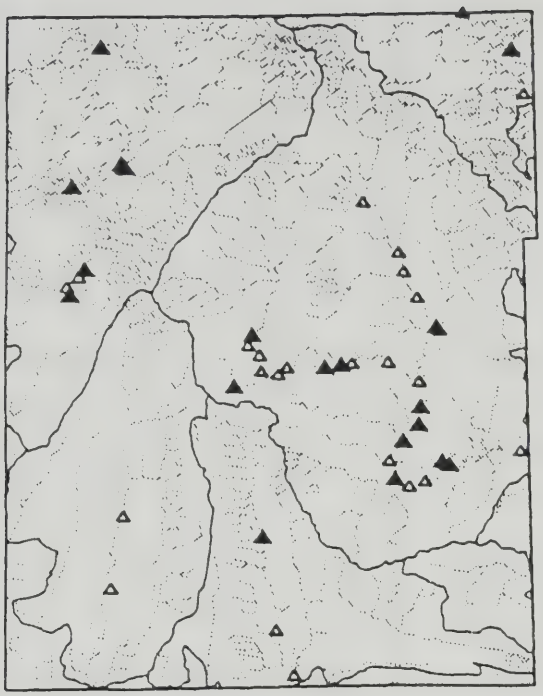


LARIMORE & SMITH



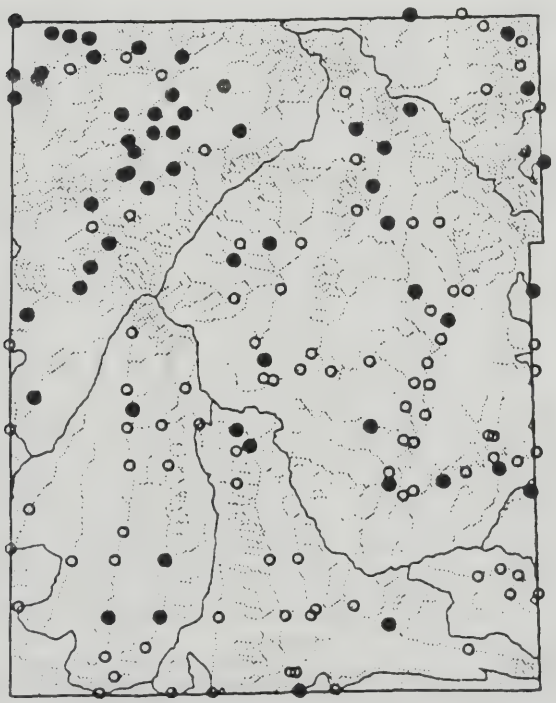
PRESENT STUDY

Fig A17. Closed circle -Presence, Open circle -absence of *Luxilus cornutus* Common shiner (CMS) in Champaign County survey. Closed triangle -Presence, Open triangle -absence of Common shiner and Striped shiner (CMS/STS)

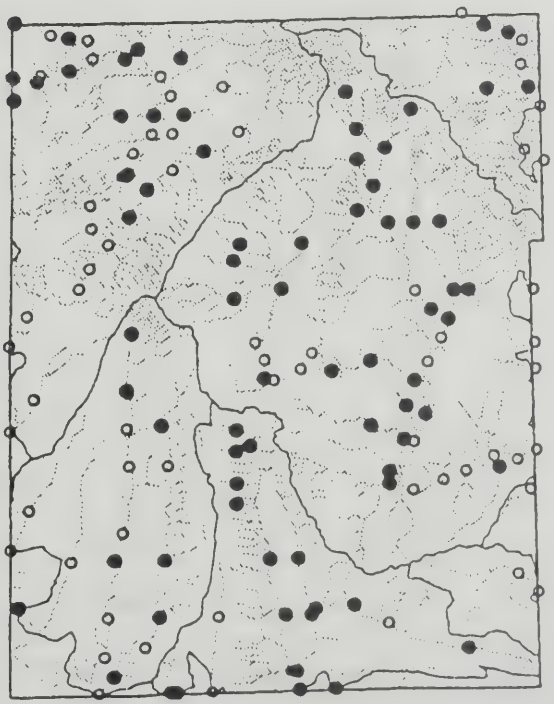


FORBES & RICHARDSON

THOMPSON & HUNT

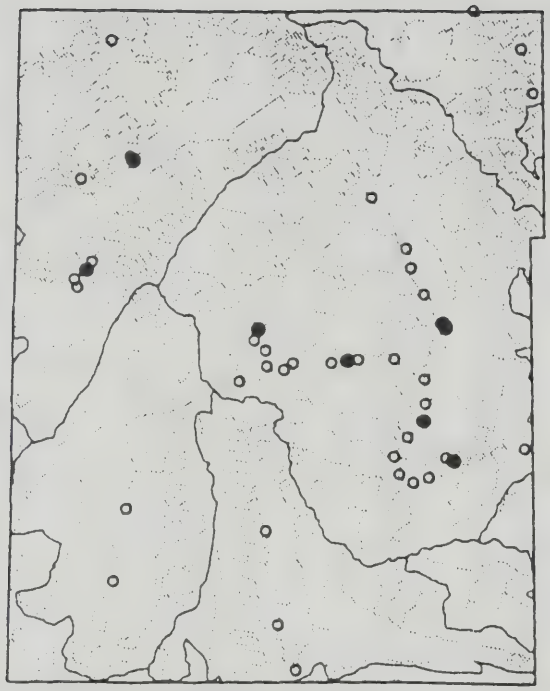


LARIMORE & SMITH



PRESENT STUDY

Fig A18. Closed circle -Presence, Open circle -absence of *Campostoma anomalum* Central stoneroller (COS) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Central stoneroller and Largescale stoneroller (COS/LCC)



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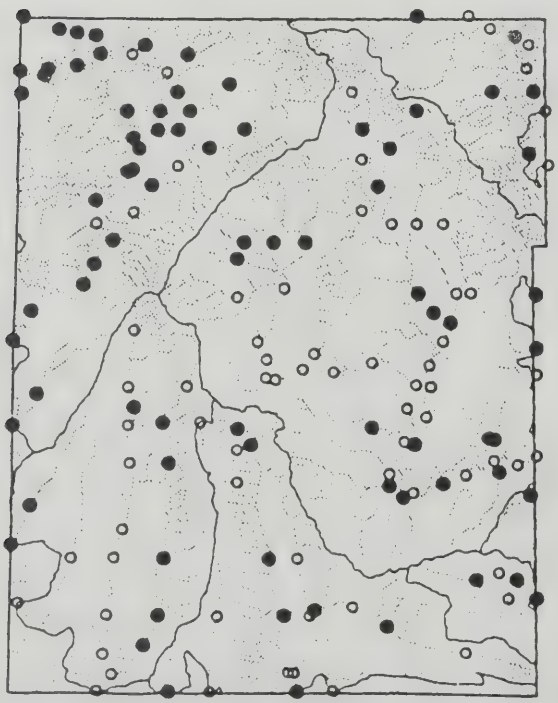
THOMPSON & HUNT



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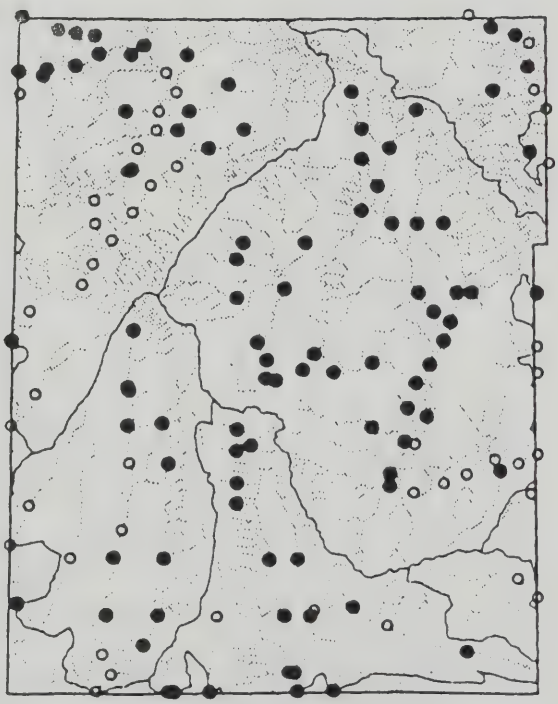
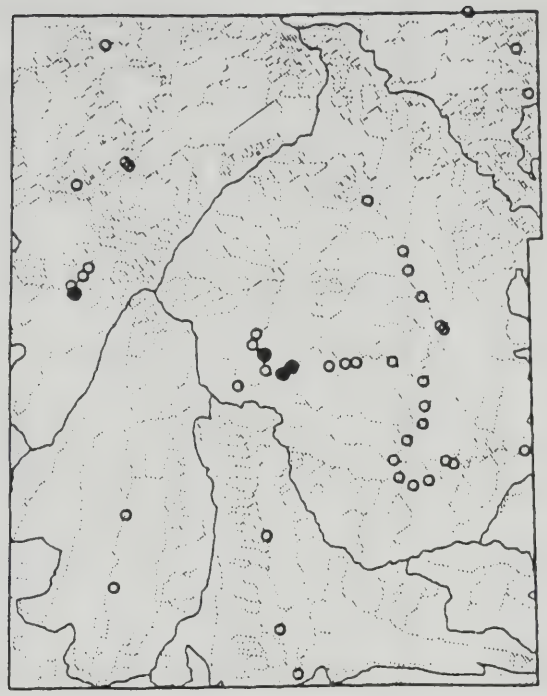


PRESENT STUDY

Fig A19. Closed circle -Presence, Open circle -absence of *Semotilus atromaculatus* Creek chub (CRC) in Champaign County survey.



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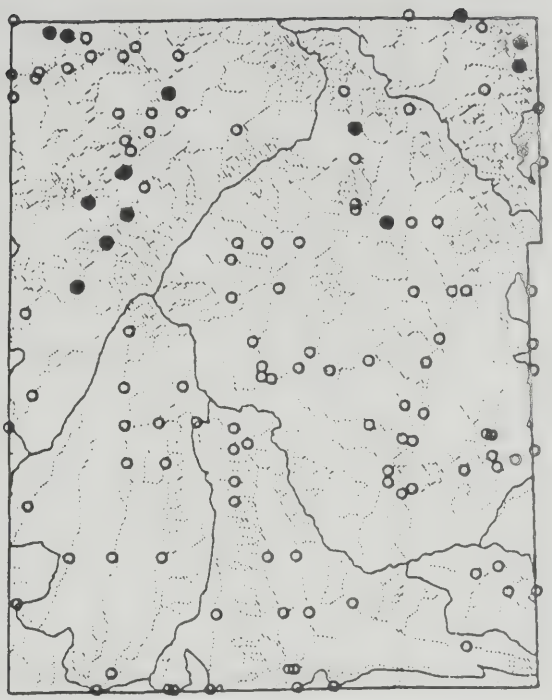

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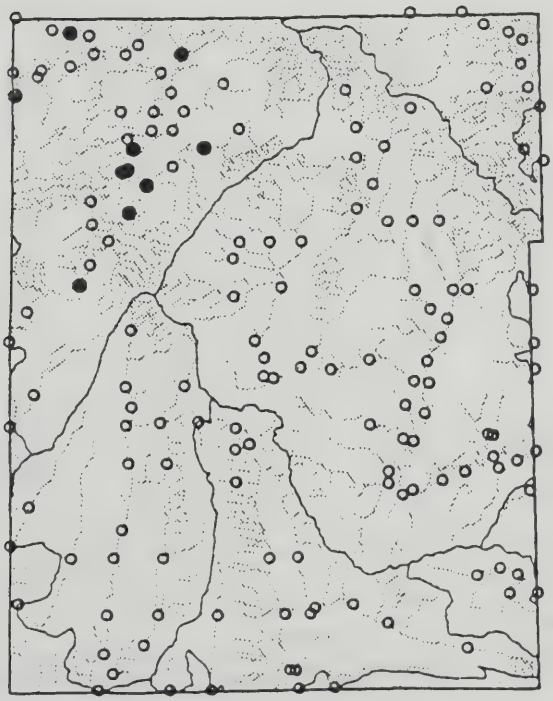
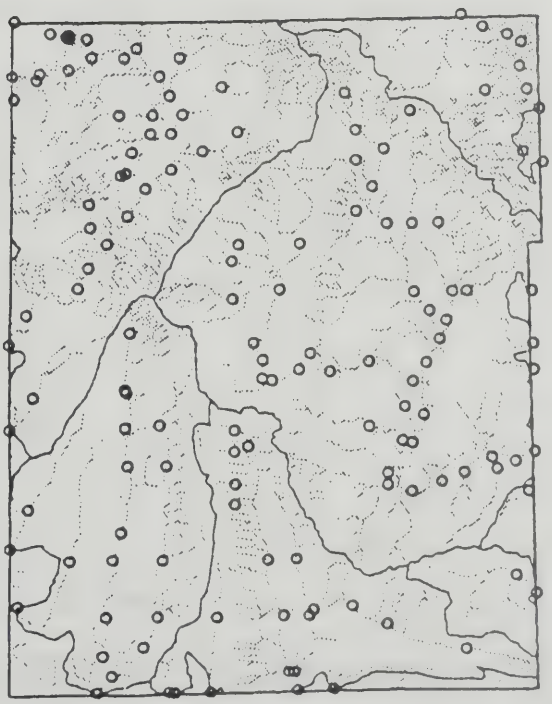
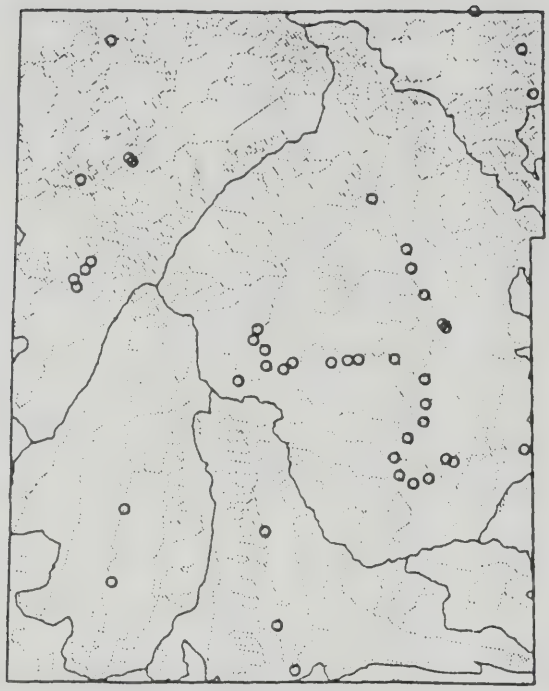


LARIMORE & SMITH

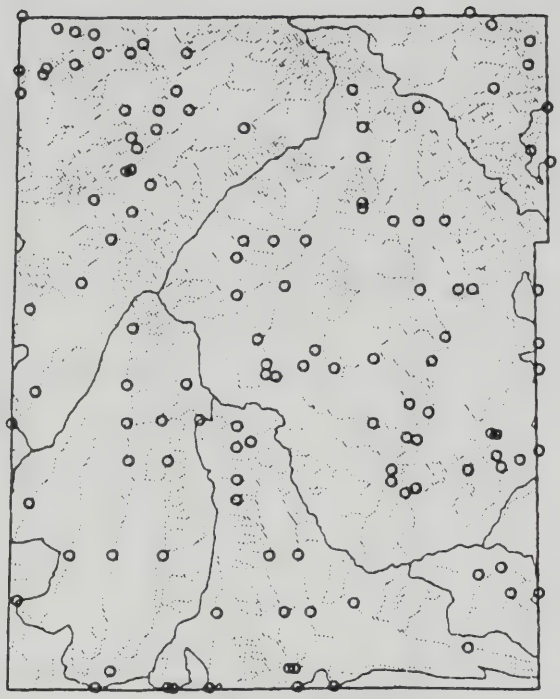


PRESENT STUDY

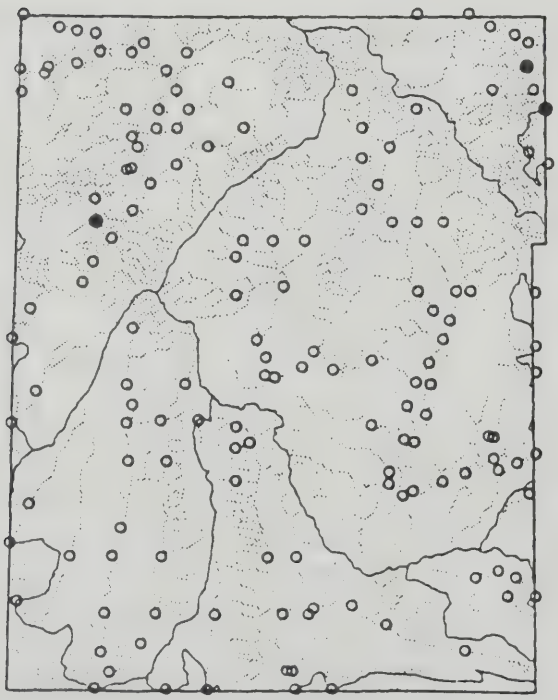
Fig A20. Closed circle -Presence, Open circle -absence of *Etheostoma flabellare* Fantail darter (FAD) in Champaign County survey.



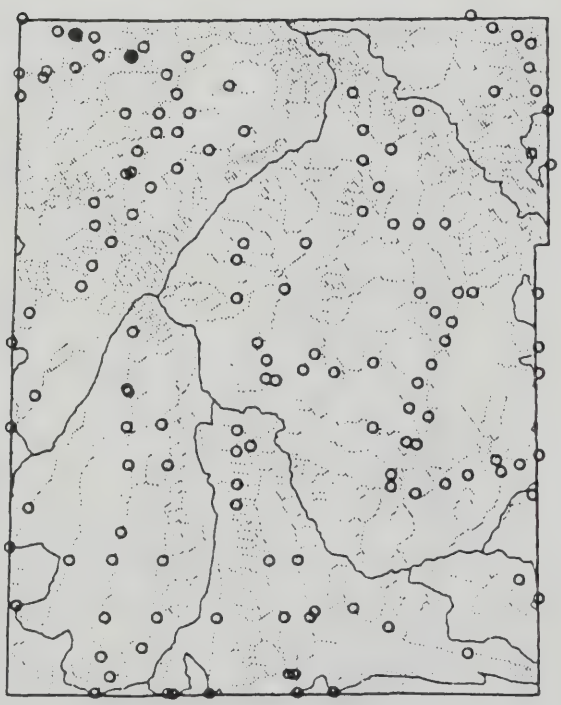
FORBES & RICHARDSON



THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A21. Closed circle -Presence, Open circle -absence of *Pylodictis olivaris* Flathead catfish (FCF) in Champaign County survey.

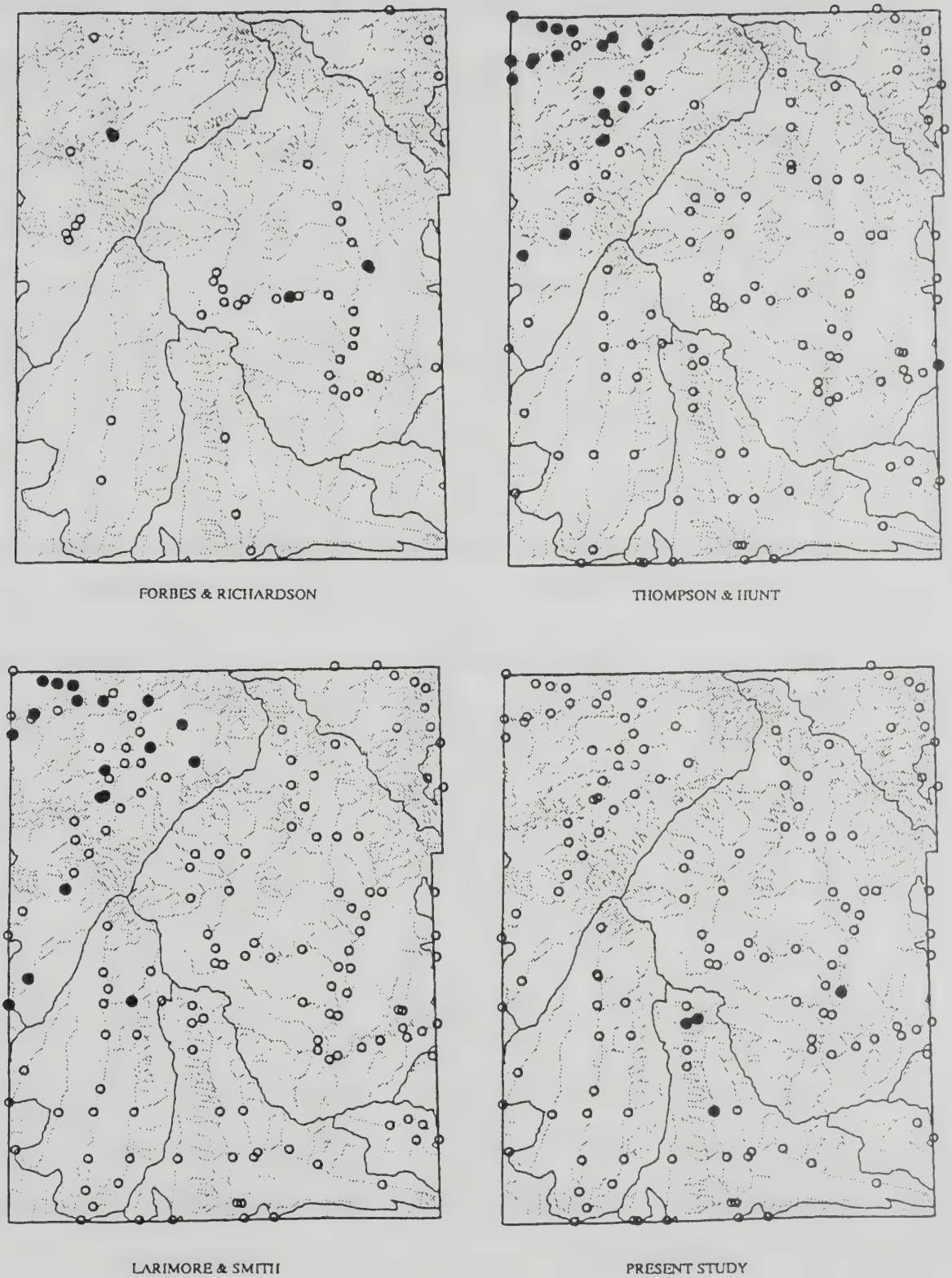


Fig A22. Closed circle -Presence, Open circle -absence of *Pimephales promelas* Fathead minnow (FHM) in Champaign County survey.

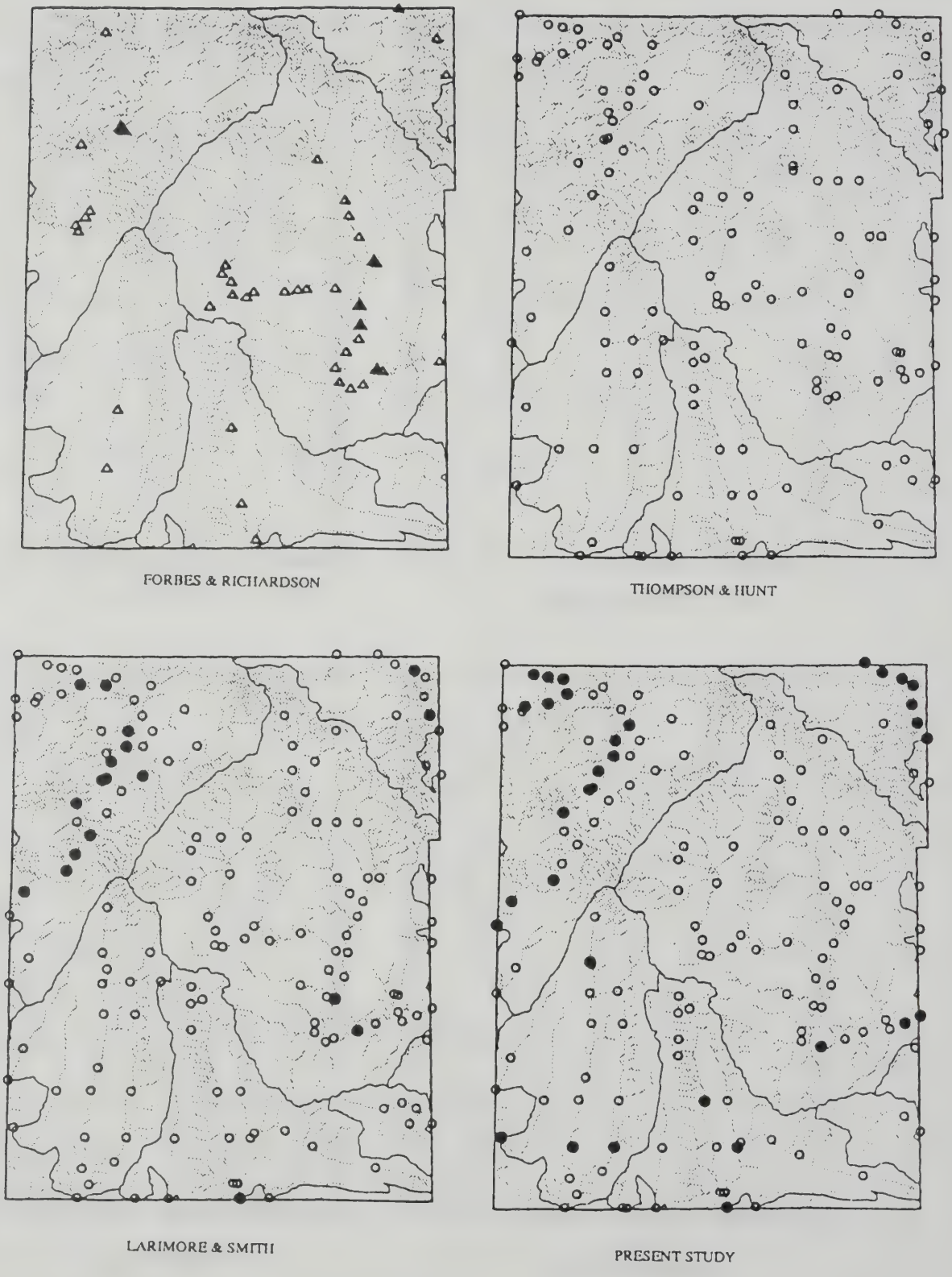
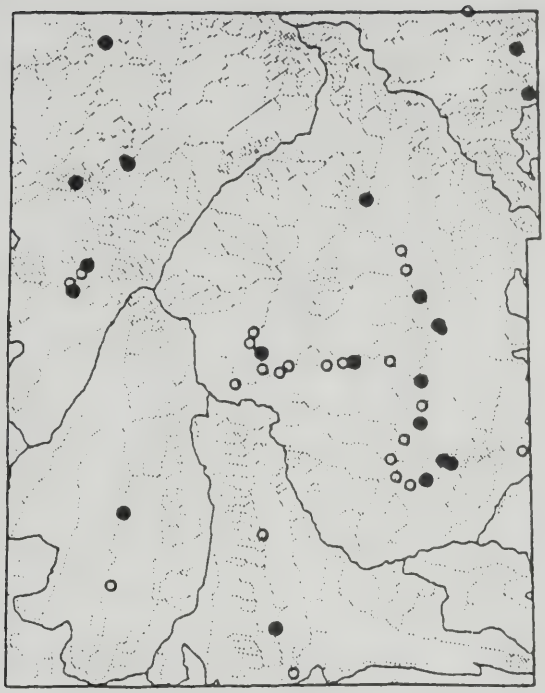


Fig A25. Closed circle -Presence, Open circle -absence of *Moxostoma erythrurum* Golden redhorse (GOR) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Black redhorse and Golden redhorse (BLR/GOR)



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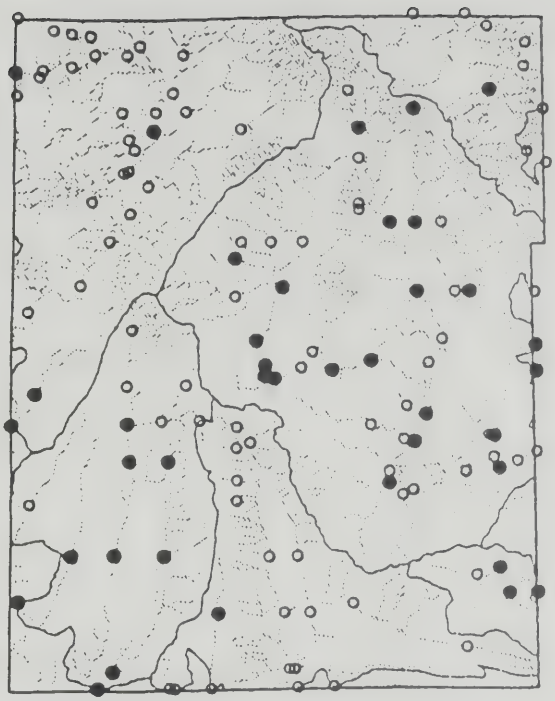
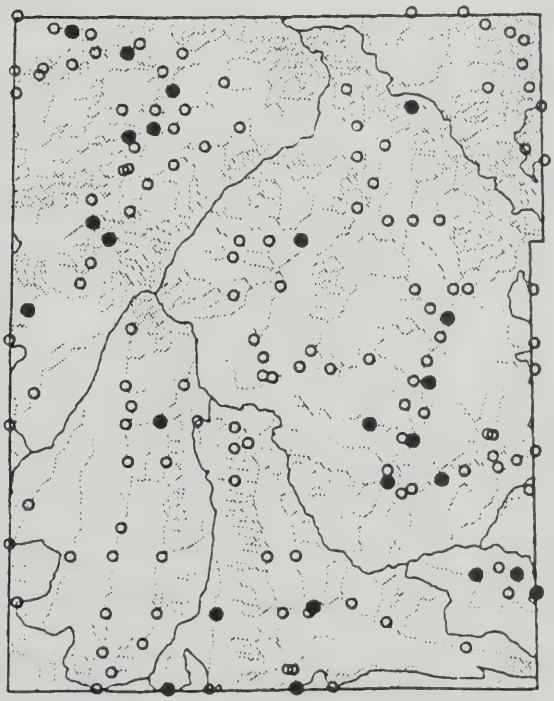


THOMPSON & HUNT



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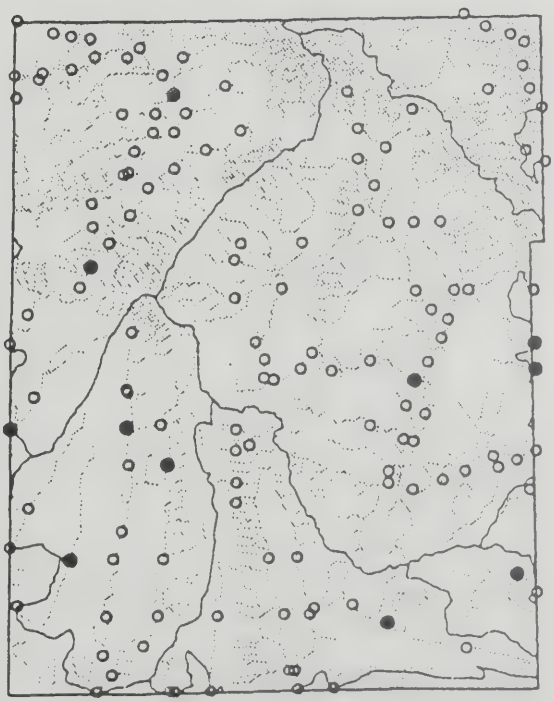


PRESENT STUDY

Fig A26. Closed circle -Presence, Open circle -absence of *Notemigonus crysoleucas* Golden shiner (GOS) in Champaign County survey.

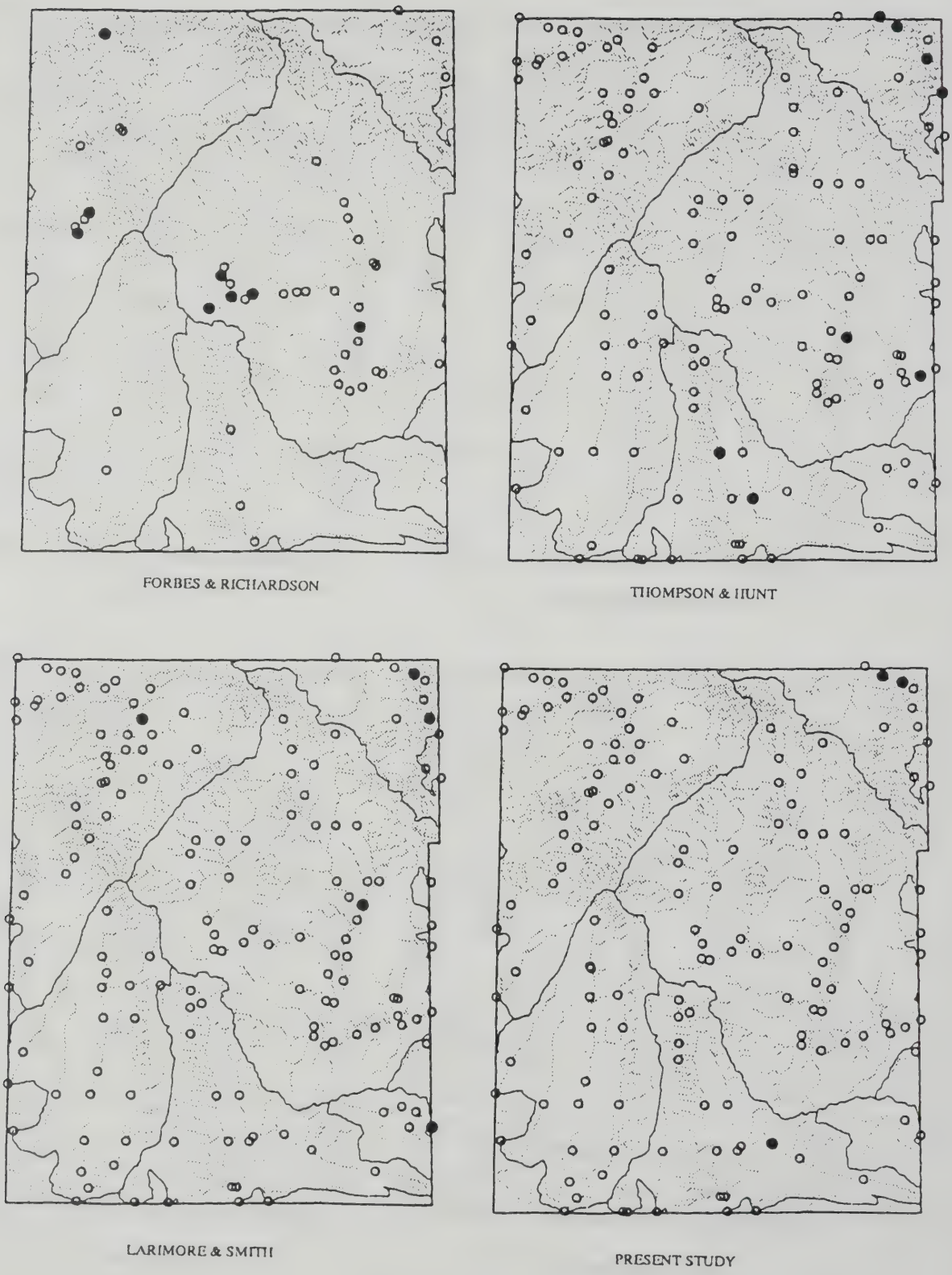


Fig A27. Closed circle -Presence, Open circle -absence of *Etheostoma blennioides* Greenside darter (GRD) in Champaign County survey.

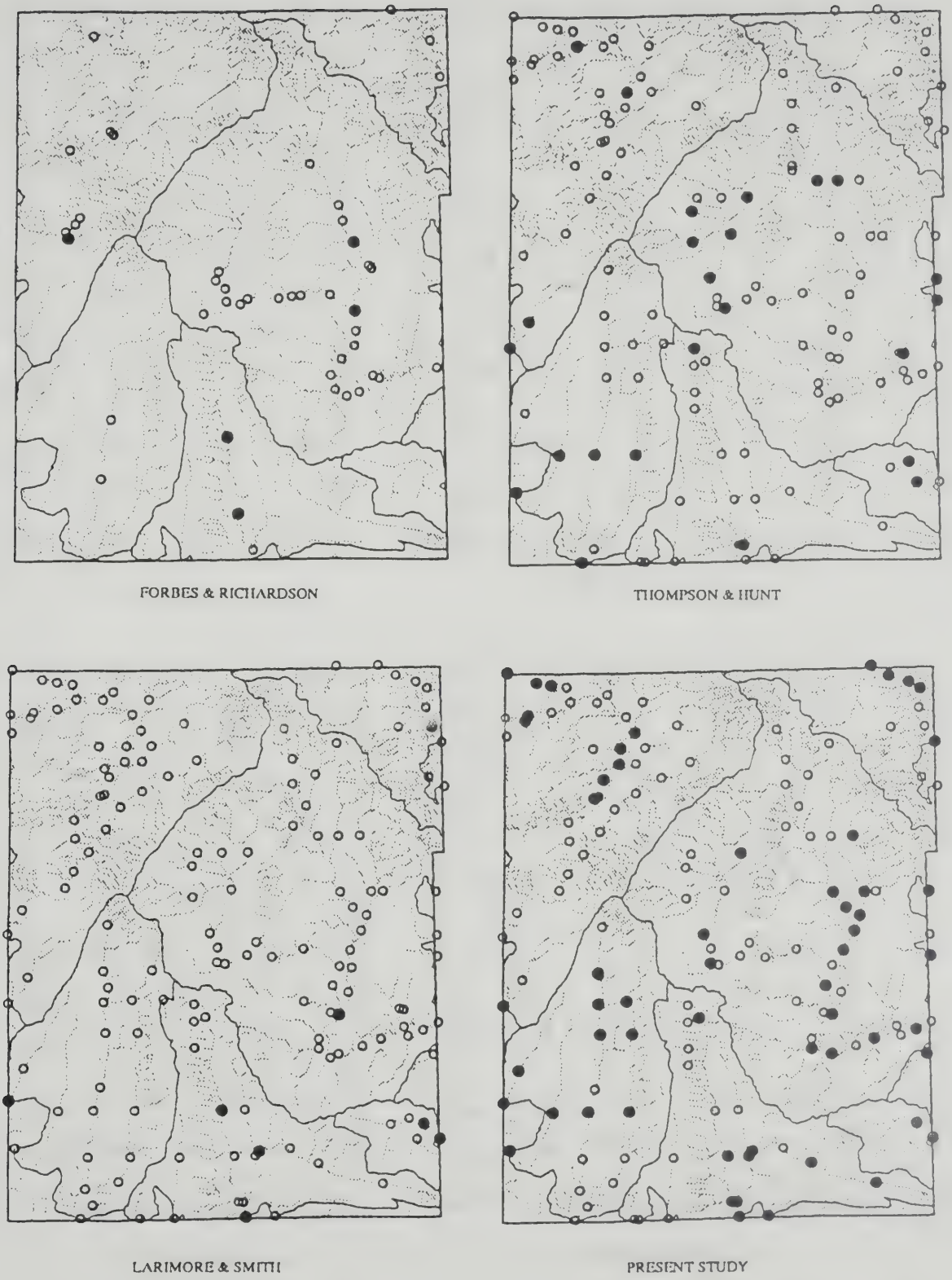


Fig A28. Closed circle -Presence, Open circle -absence of *Esox americanus* Grass pickerel (GRP) in Champaign County survey.

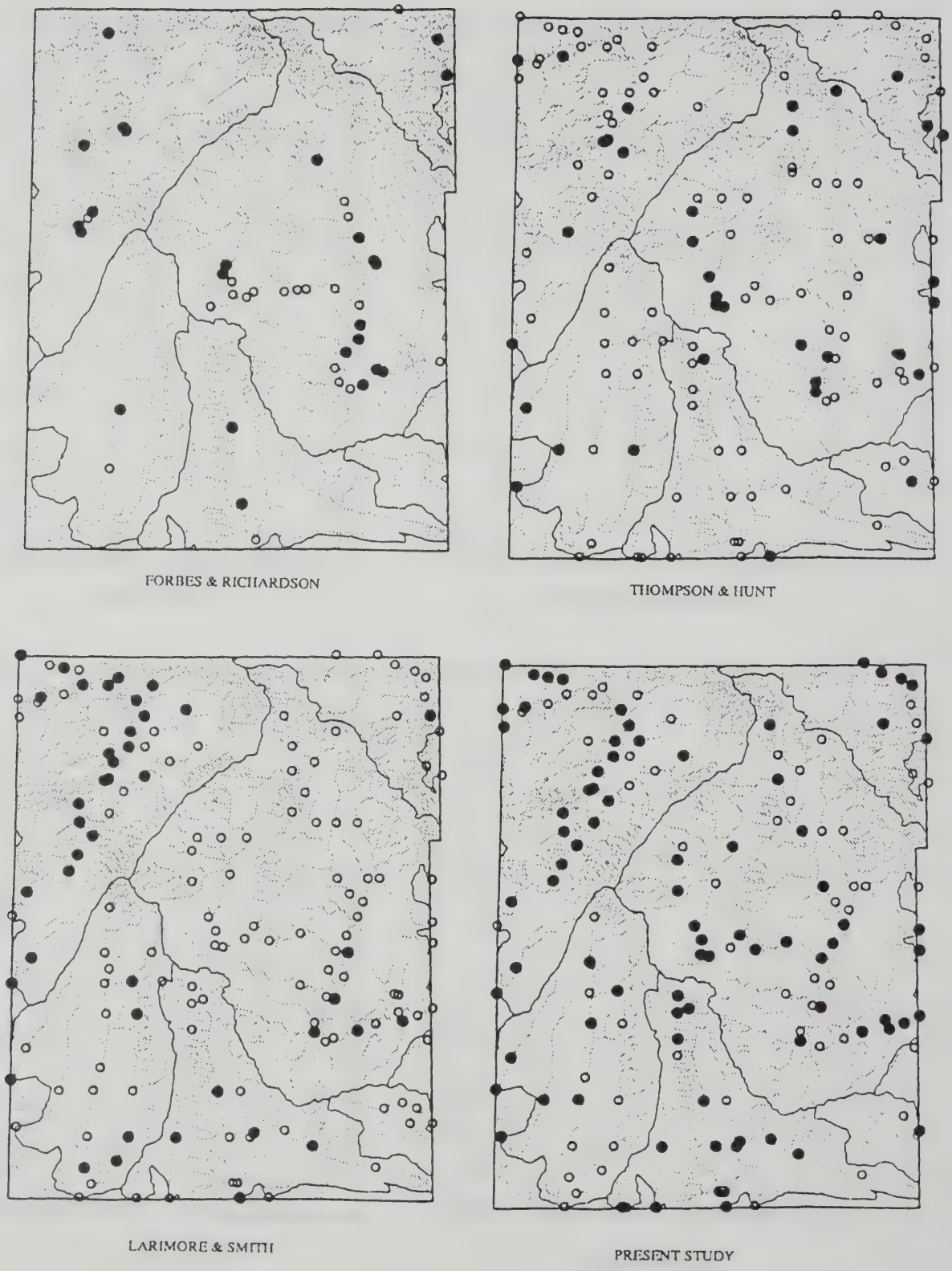


Fig A29. Closed circle -Presence, Open circle -absence of *Lepomis cyanellus* Green sunfish (GSF) in Champaign County survey.

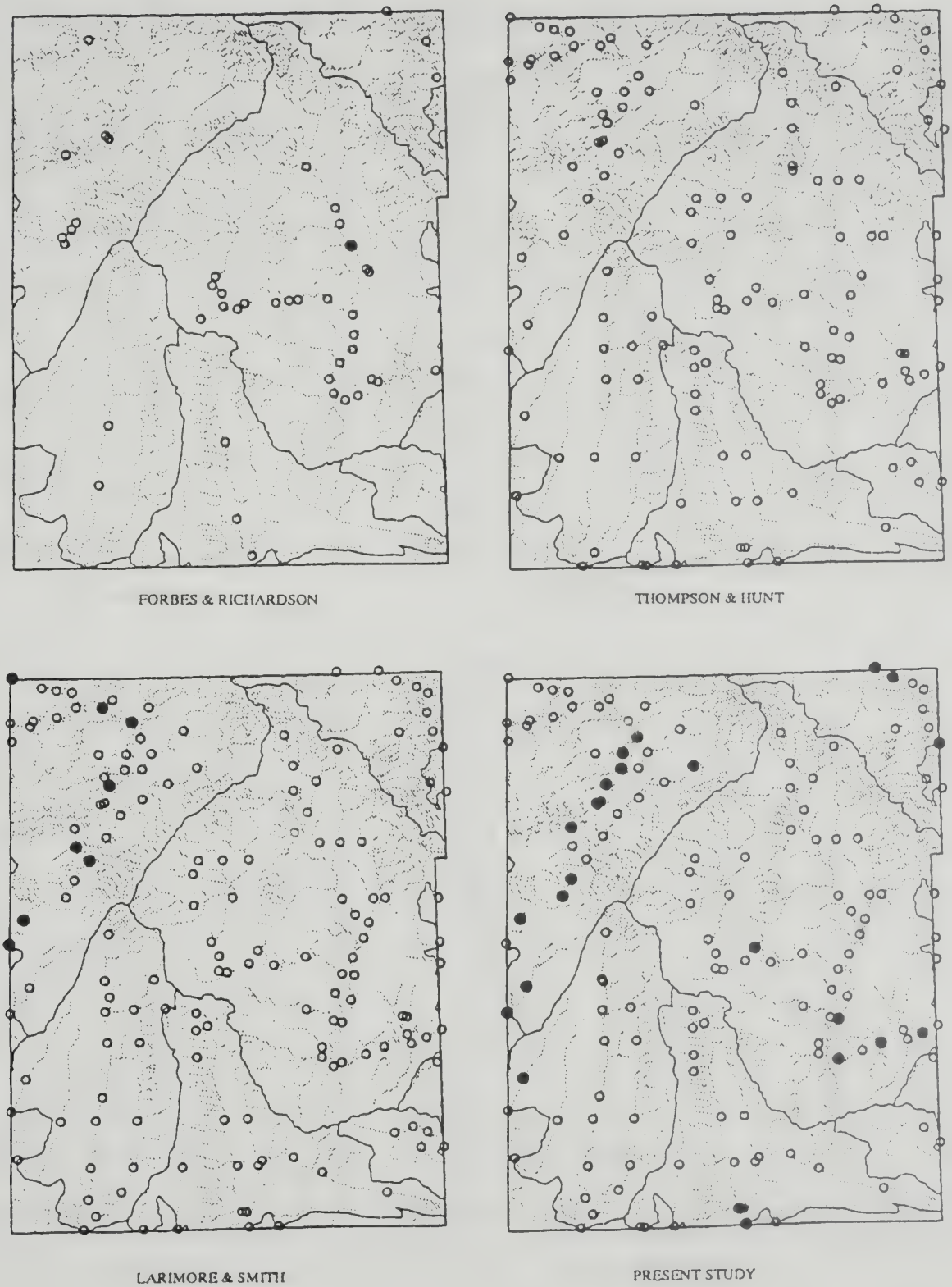


Fig A30. Closed circle -Presence, Open circle -absence of *Dorosoma cepedianum* Gizzard shad (GZS) in Champaign County survey.

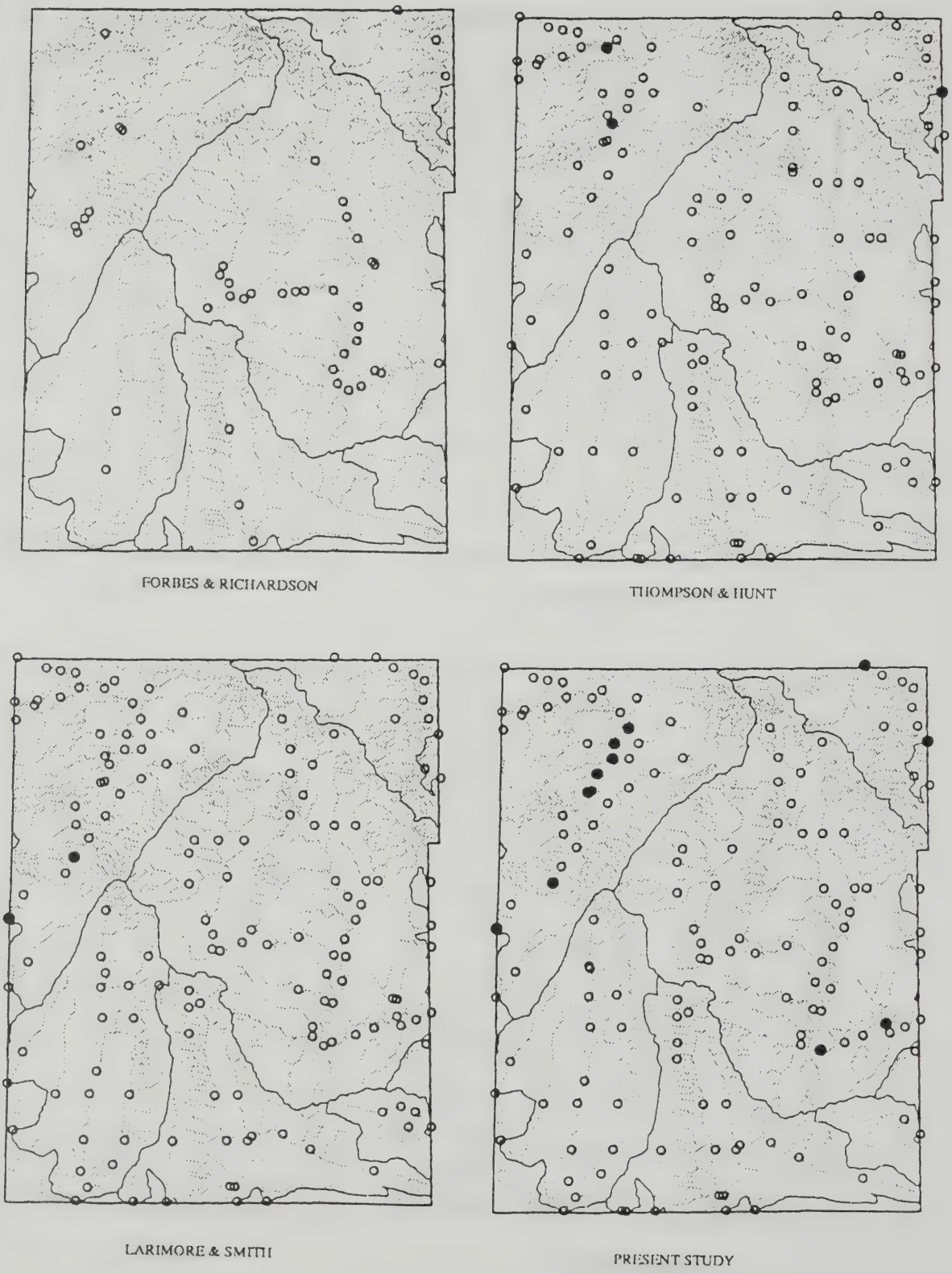
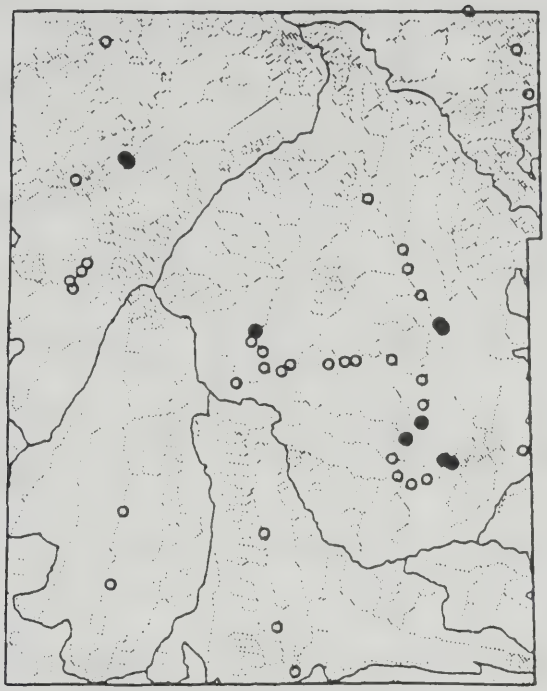


Fig A31. Closed circle -Presence, Open circle -absence of *Carpiodes velifer* Highfin carpsucker (HFC) in Champaign County survey.



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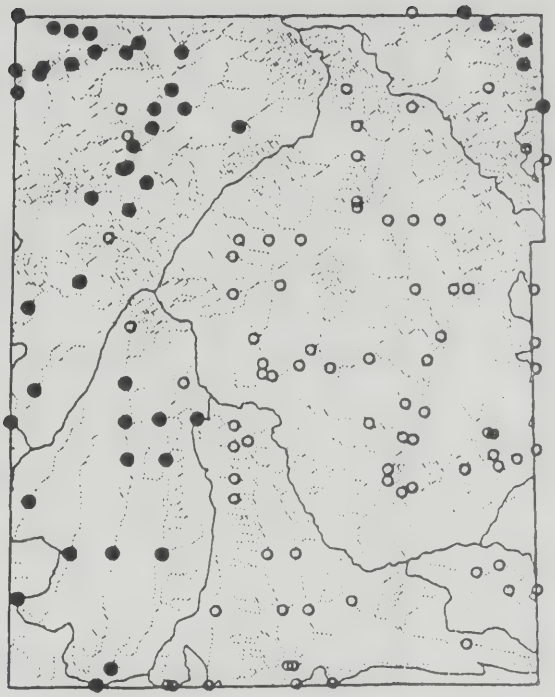

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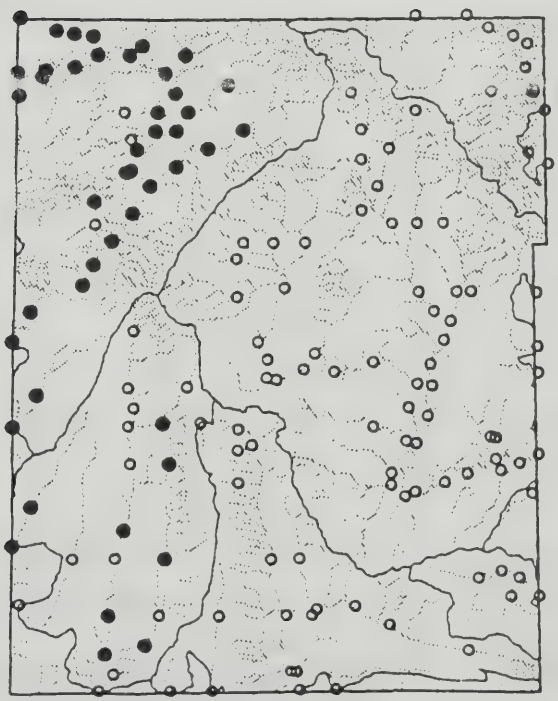

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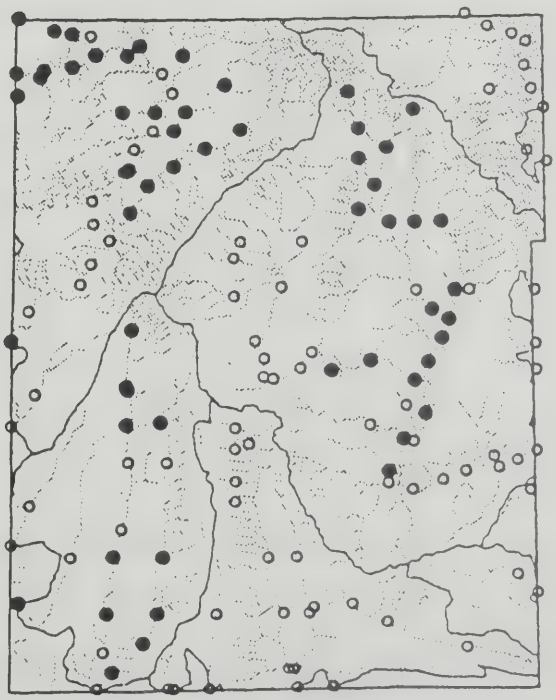


PRESENT STUDY

Fig A32. Closed circle -Presence, Open circle -absence of *Nocomis biguttatus* Hornyhead chub (HOC) in Champaign County survey.

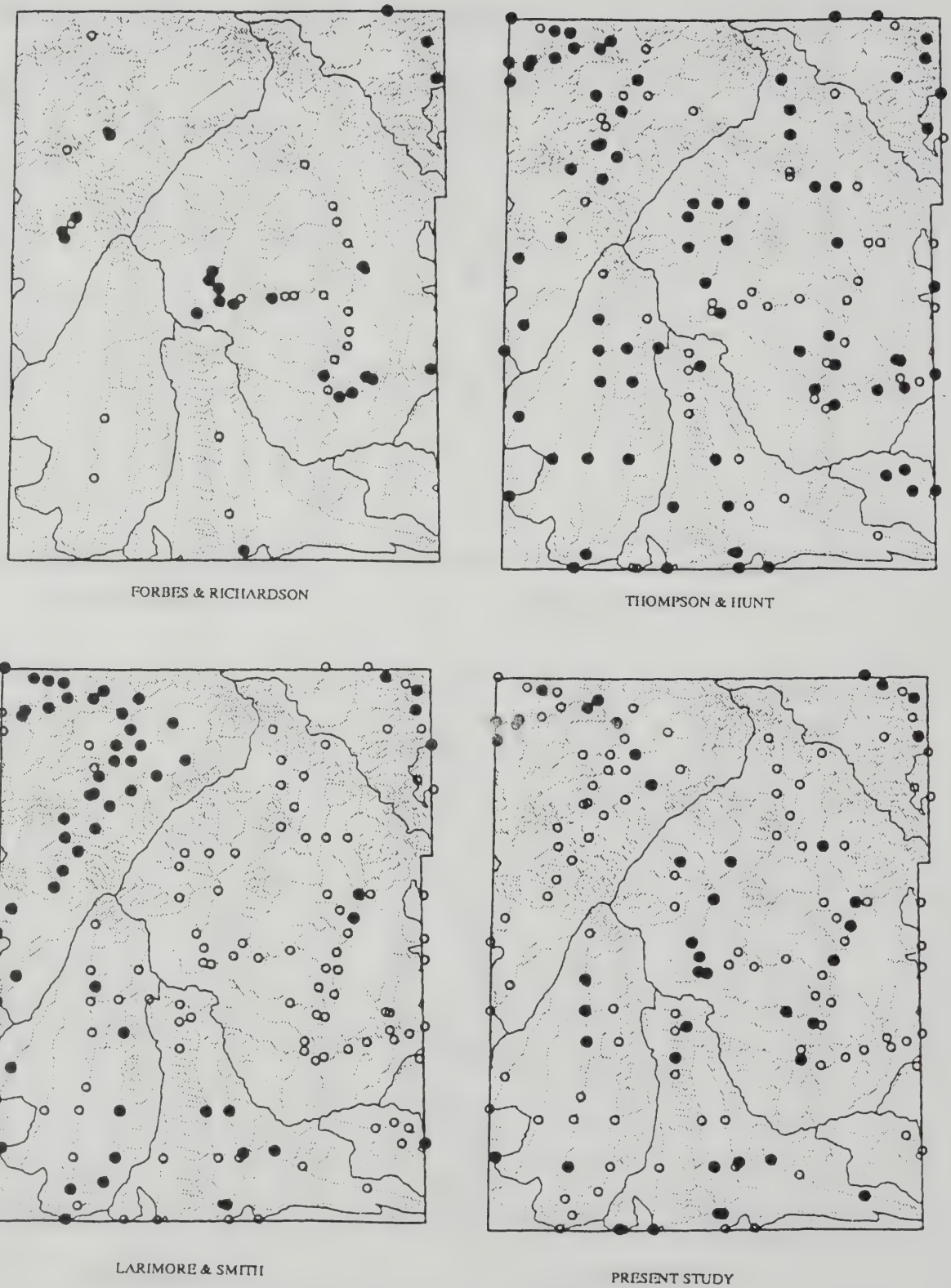


Fig A33. Closed circle -Presence, Open circle -absence of *Etheostoma nigrum* Johnny darter (JOD) in Champaign County survey.

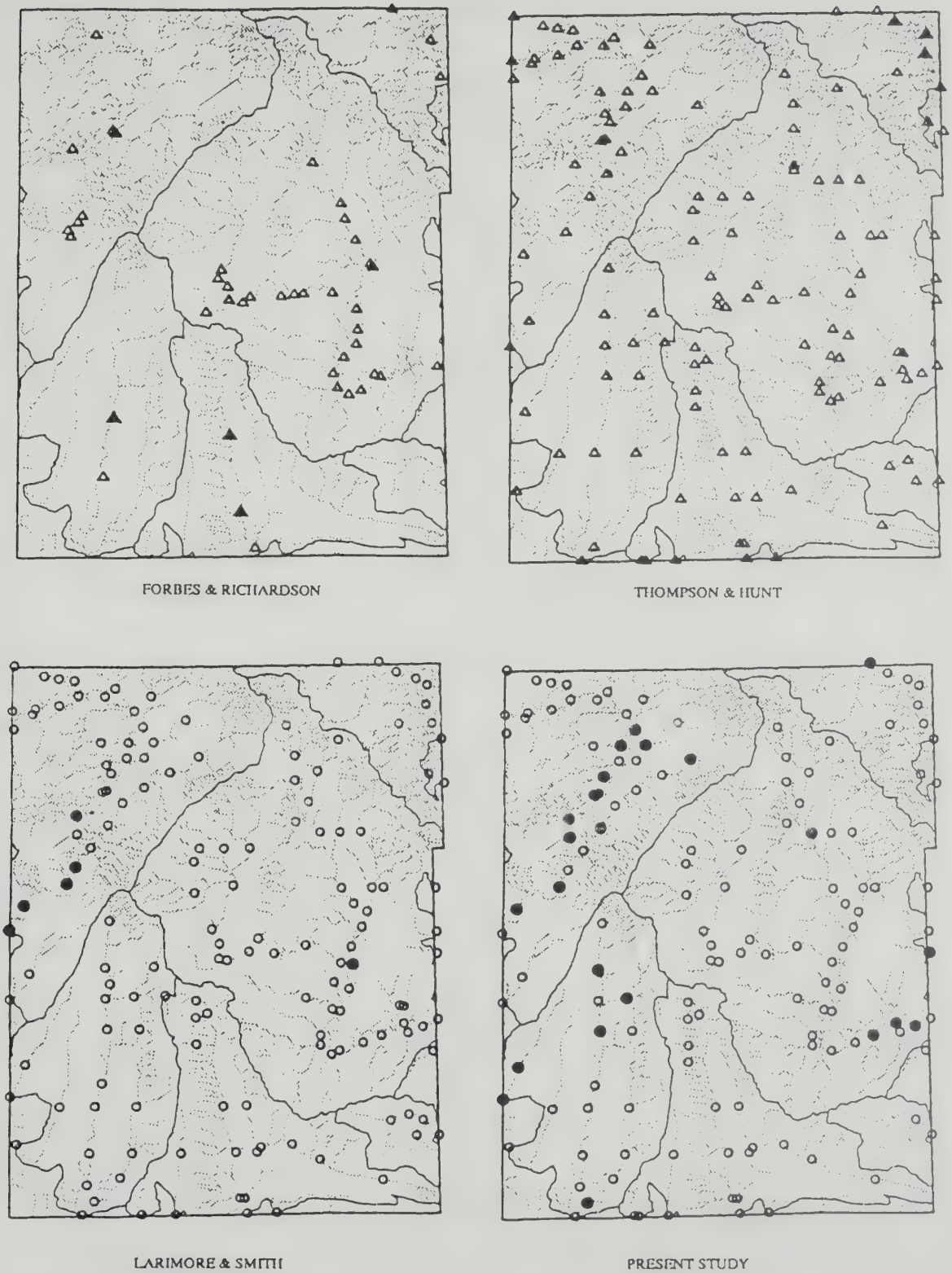
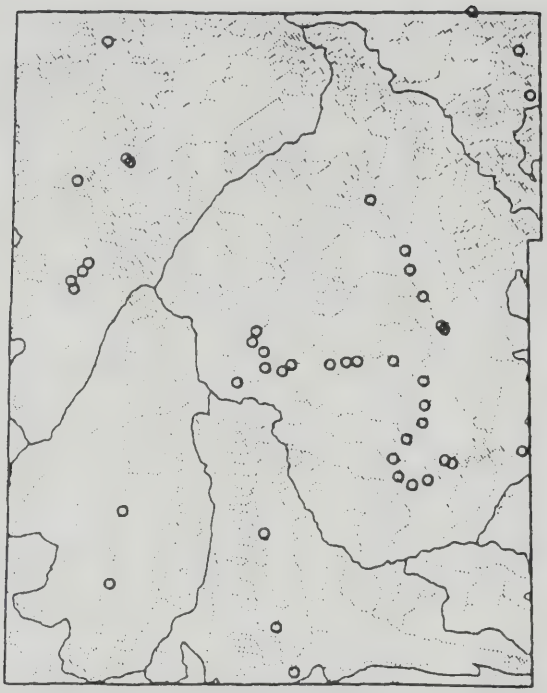


Fig A34. Closed circle -Presence, Open circle -absence of *Micropterus salmoides* Largemouth bass (LMB) in Champaign County survey. Closed triangles -Presence, Open triangles -absence of Largemouth bass and Spotted bass (LMB/SPB)



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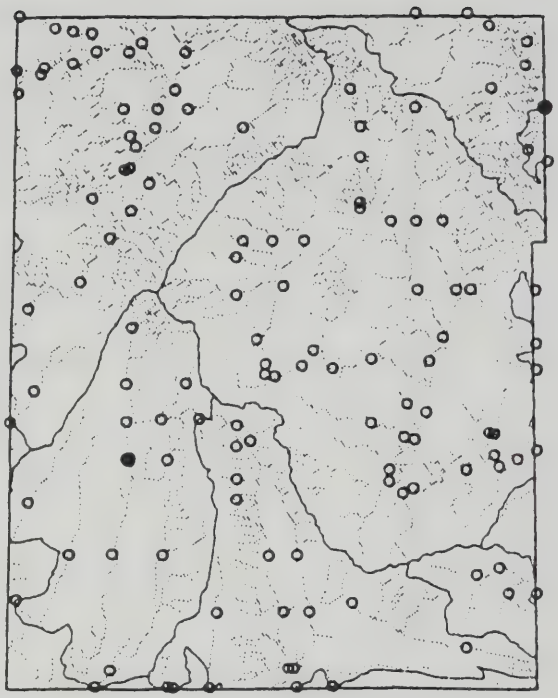
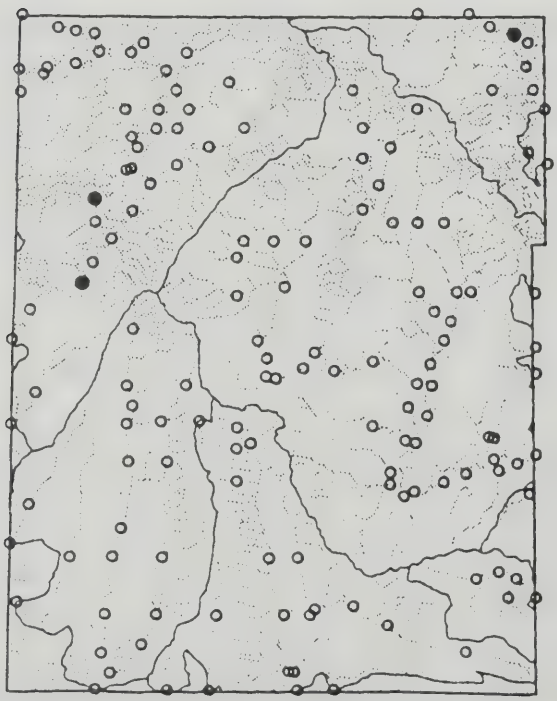


THOMPSON & HUNT



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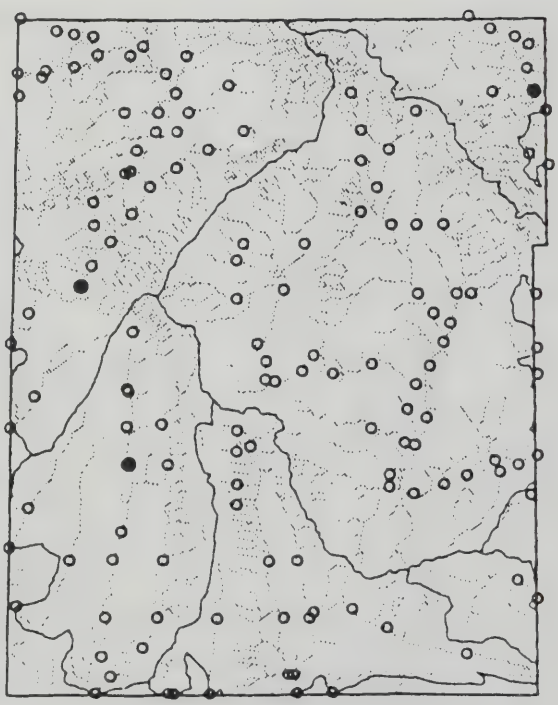


PRESENT STUDY

Fig A35. Closed circle -Presence, Open circle -absence of *Percina caprodes* Logperch (LOP) in Champaign County survey.

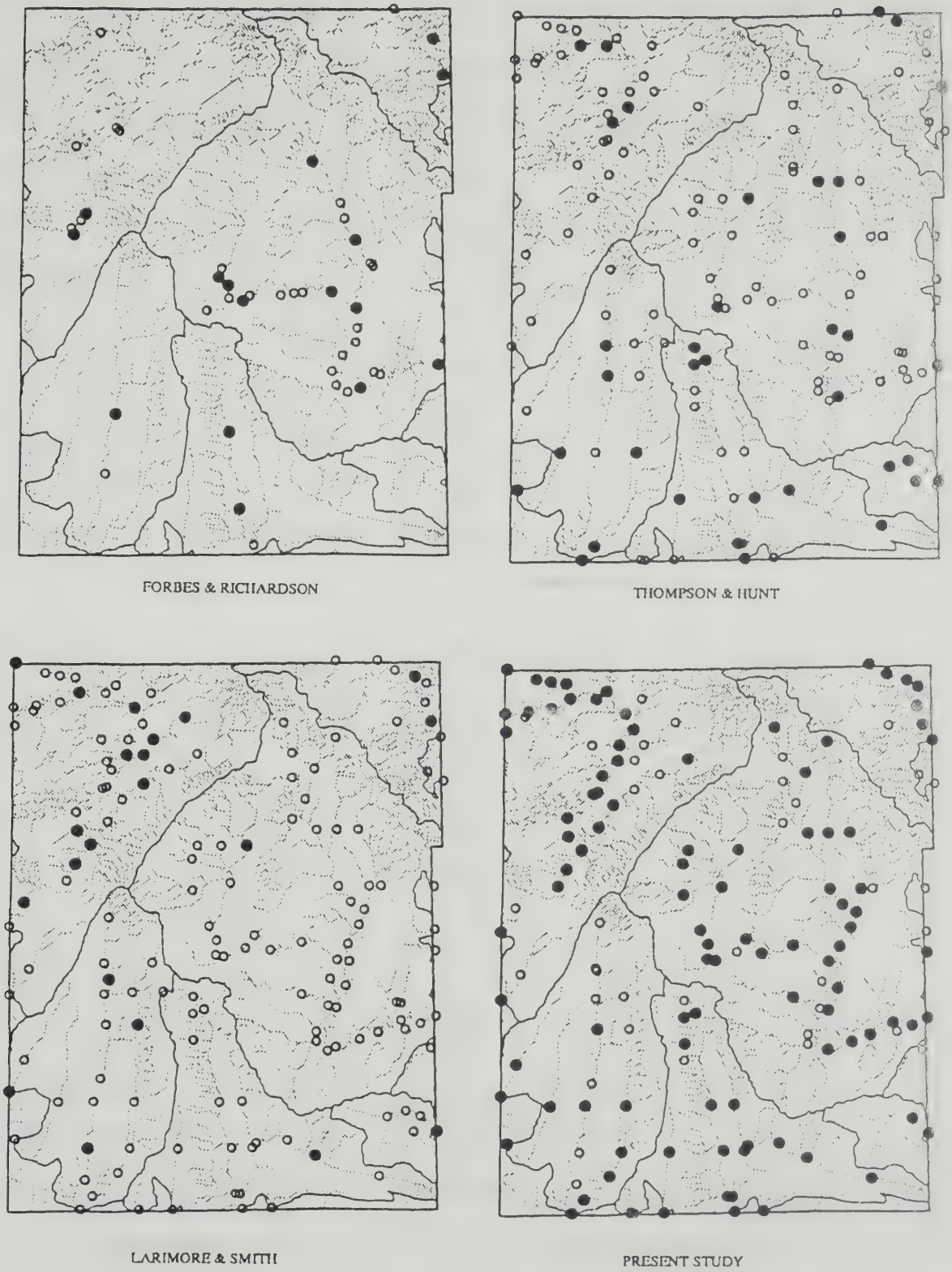
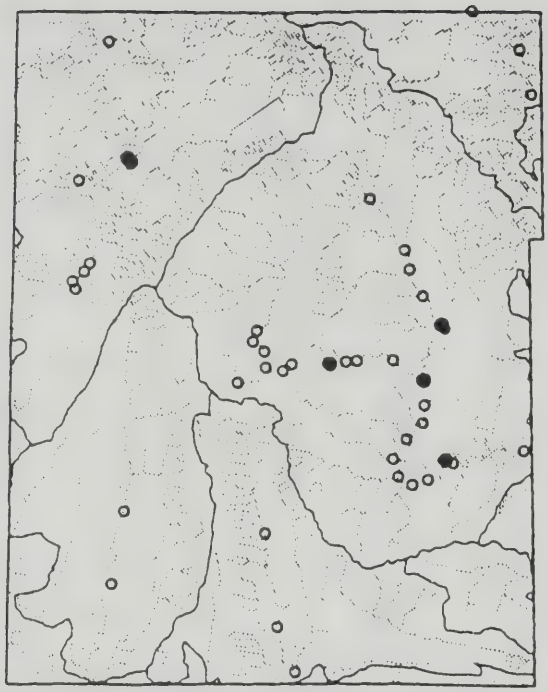
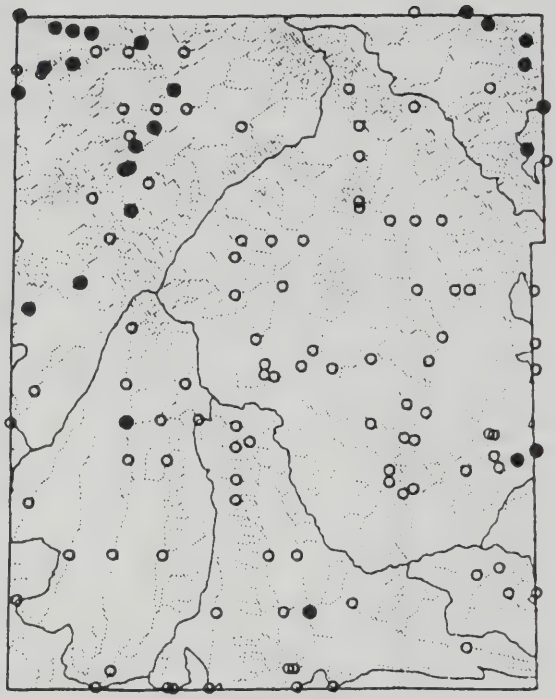


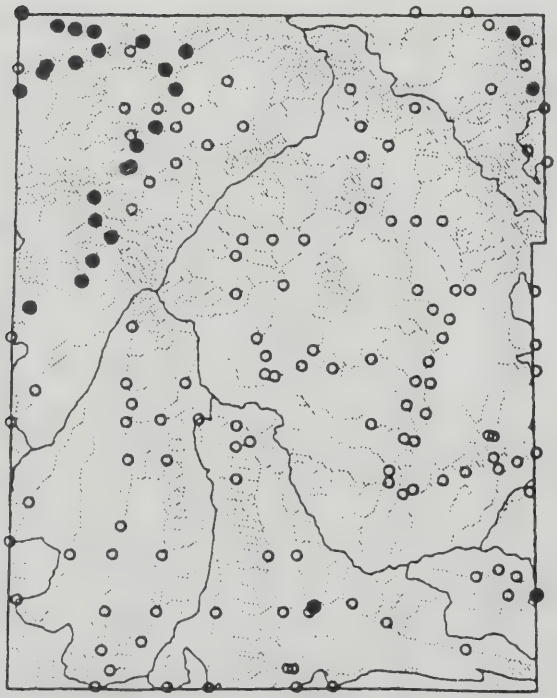
Fig A36. Closed circle -Presence, Open circle -absence of *Lepomis megalotis* Longear sunfish (LOS) in Champaign County survey.



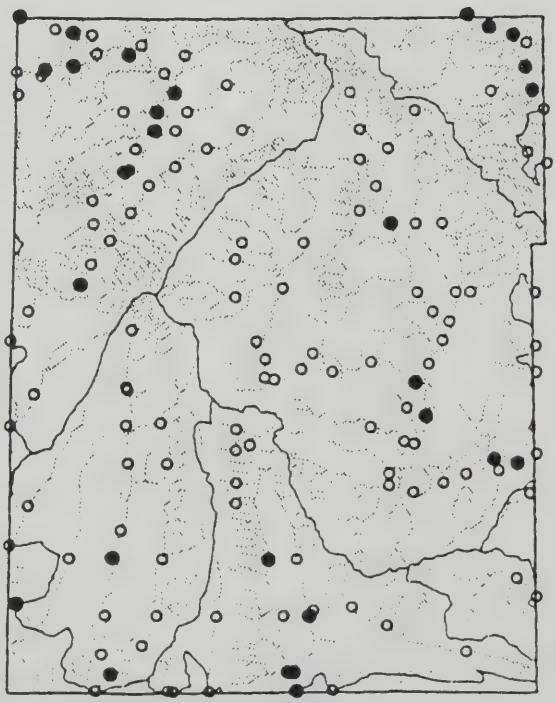
FORBES & RICHARDSON



THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A37. Closed circle -Presence, Open circle -absence of *Hypentelium nigricans* Northern hogsucker (NHS) in Champaign County survey.

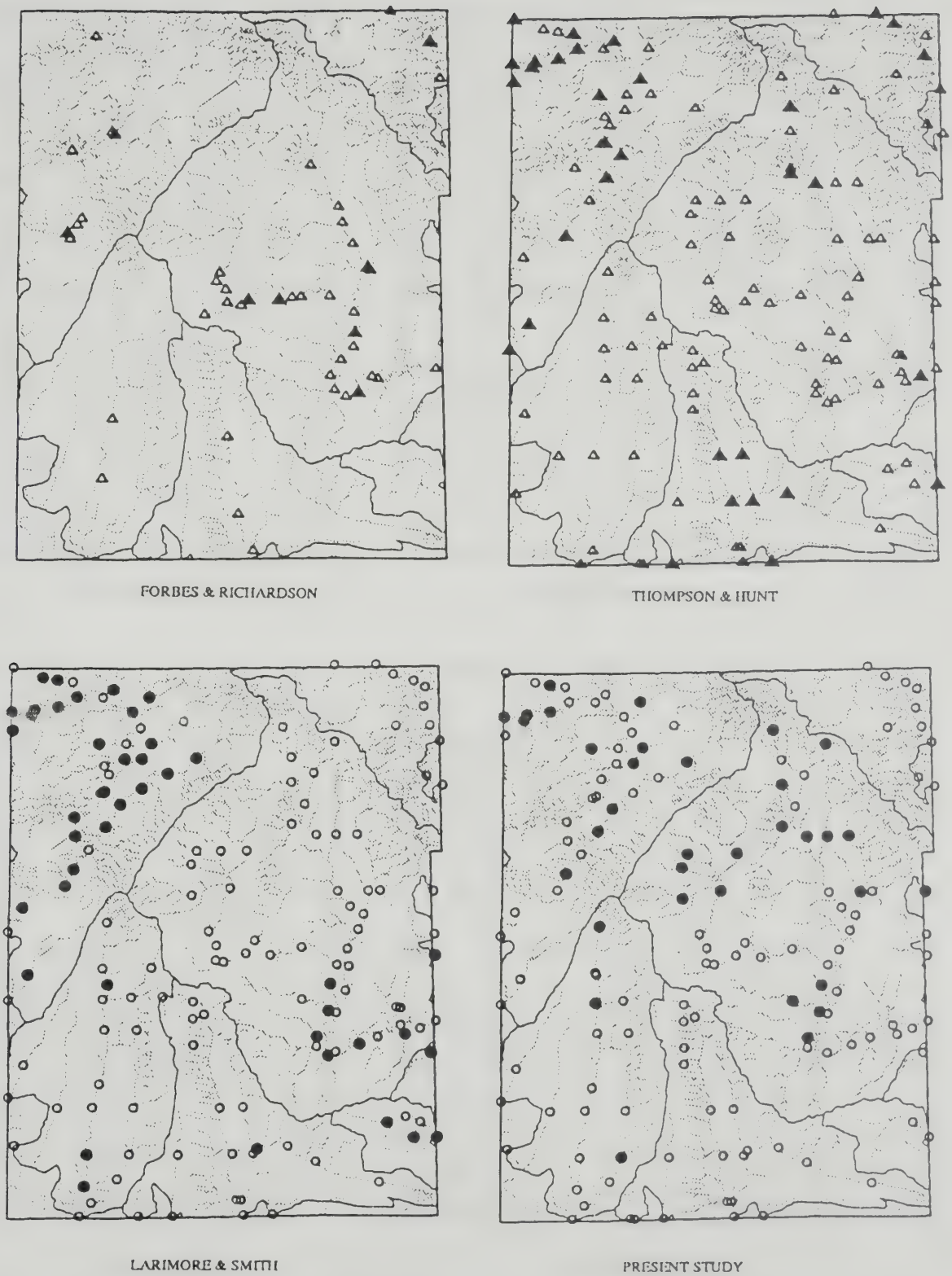
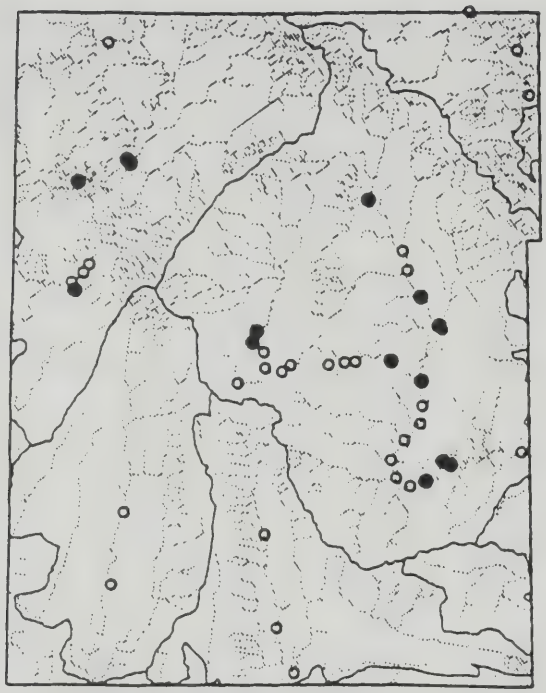


Fig A38. Closed circle -Presence, Open circle -absence of *Etheostoma spectabile* Orangethroat darter (ORD) in Champaign County survey.
Closed triangles -Presence, Open triangles -absence of Orangethroat darter and Rainbow darter (ORD/RAD)



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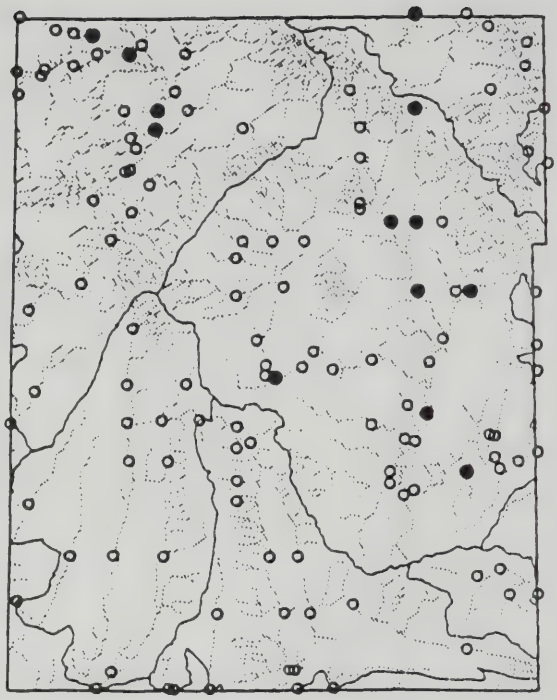

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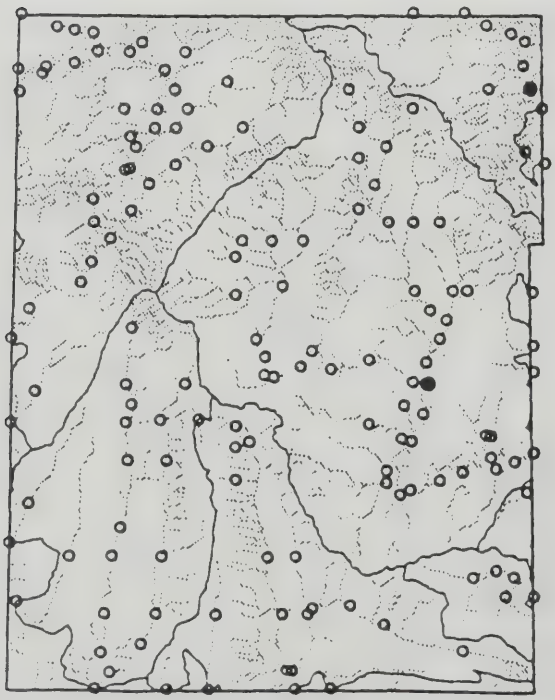
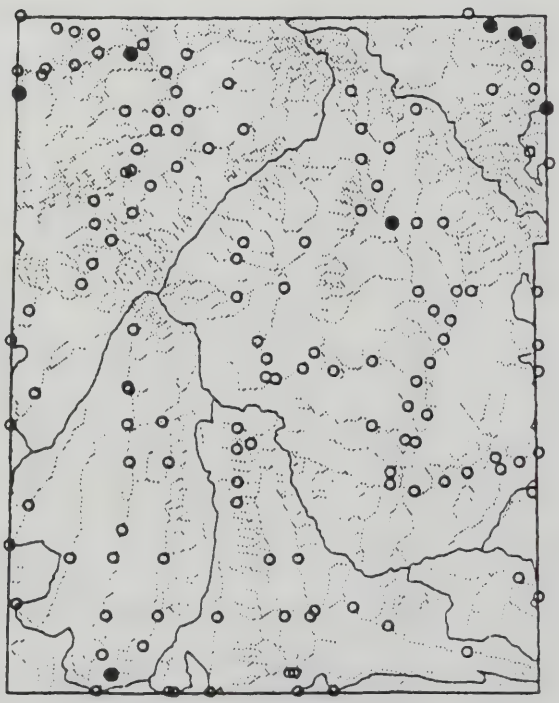
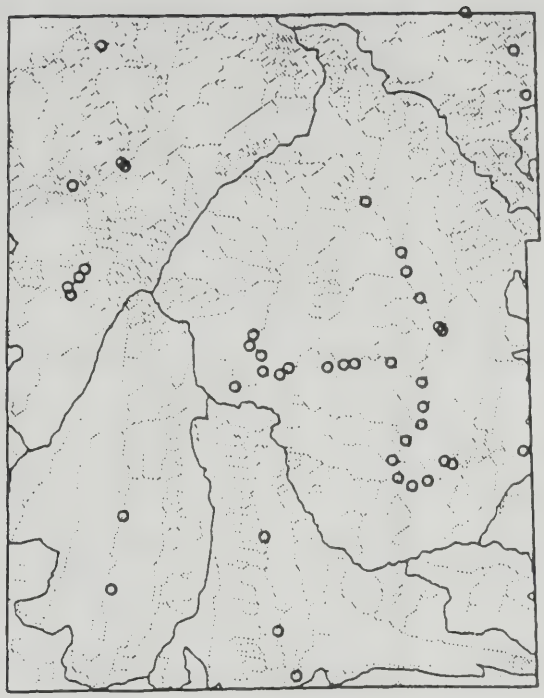


LARIMORE & SMITH

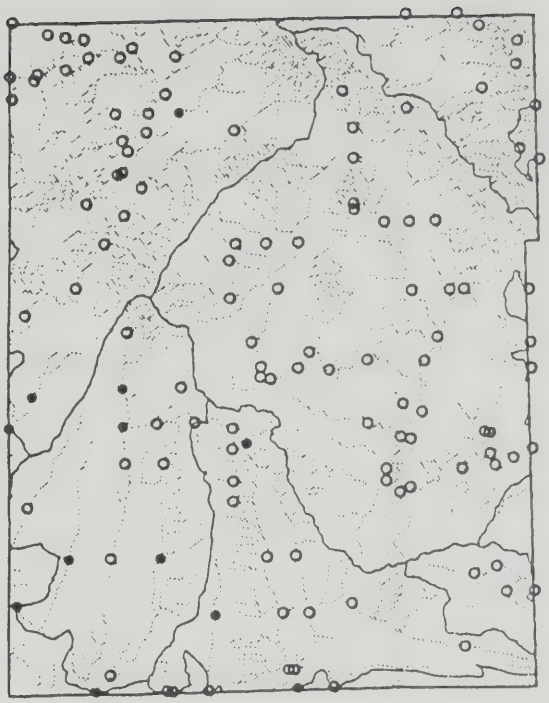


PRESENT STUDY

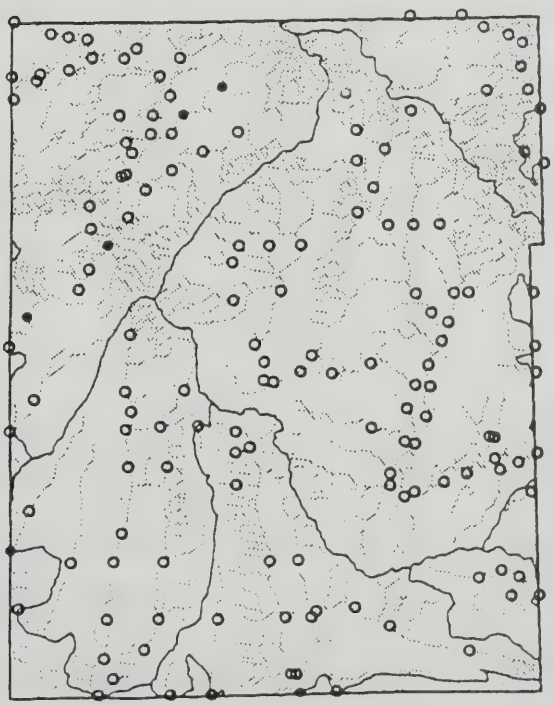
Fig A39. Closed circle -Presence, Open circle -absence of *Lepomis humilis* Orangespotted sunfish (ORS) in Champaign County survey.



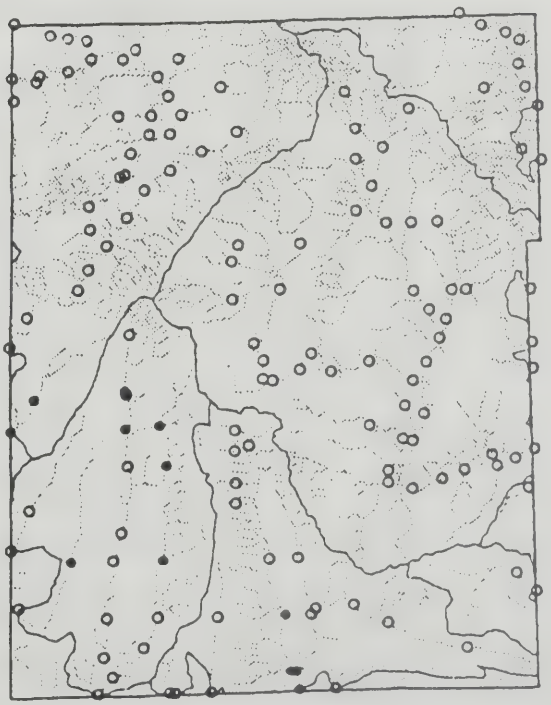
FORBES & RICHARDSON



THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A40. Open circle -Presence, Open circle -absence of *Aphredoderus sayanus* Pirate perch (PRP) in Champaign County survey.

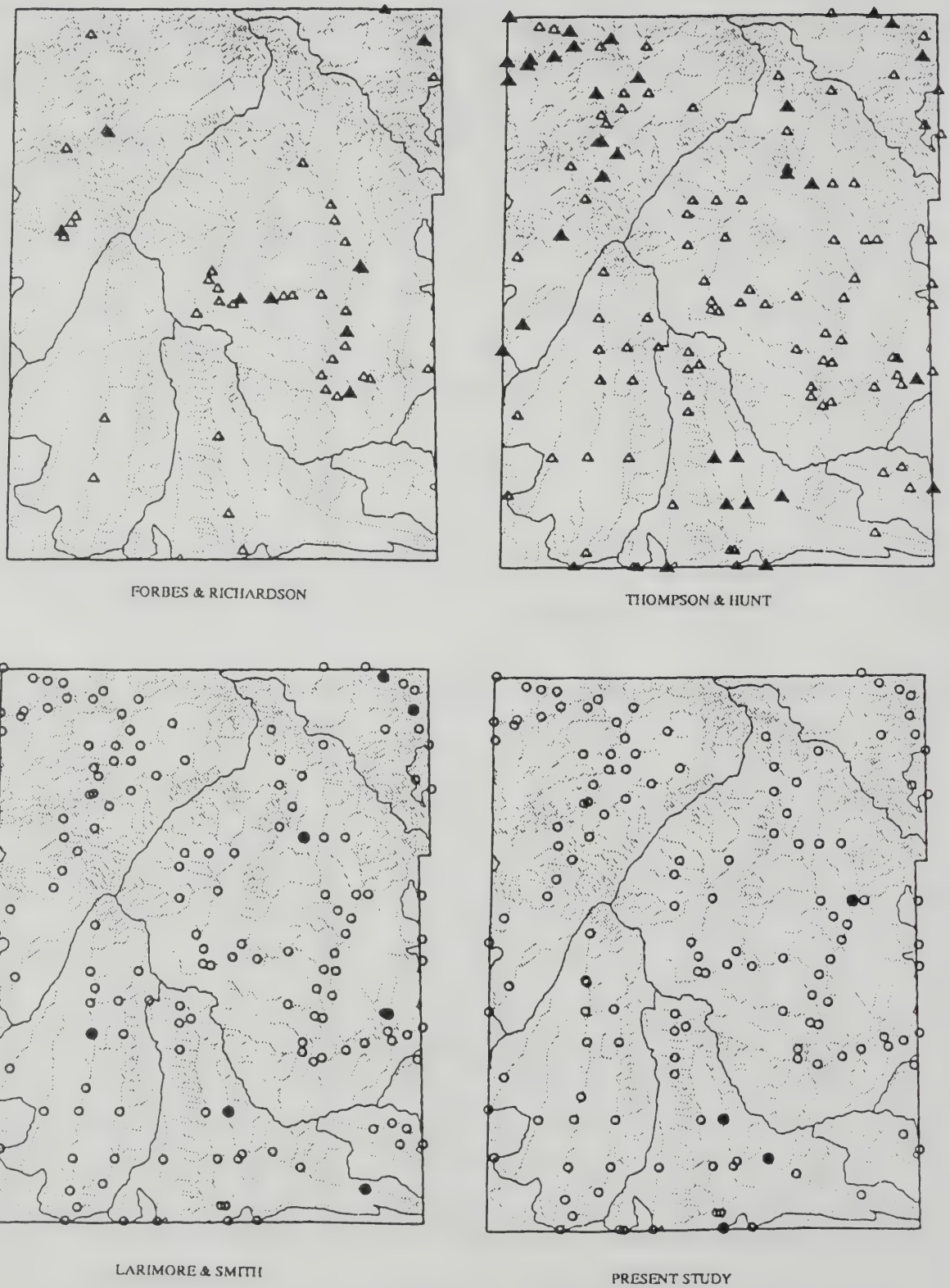


Fig A41. Closed circle -Presence, Open circle -absence of *Etheostoma caeruleum* Rainbow darter (RAD) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Orangethroat darter and Rainbow darter (ORD/RAD)

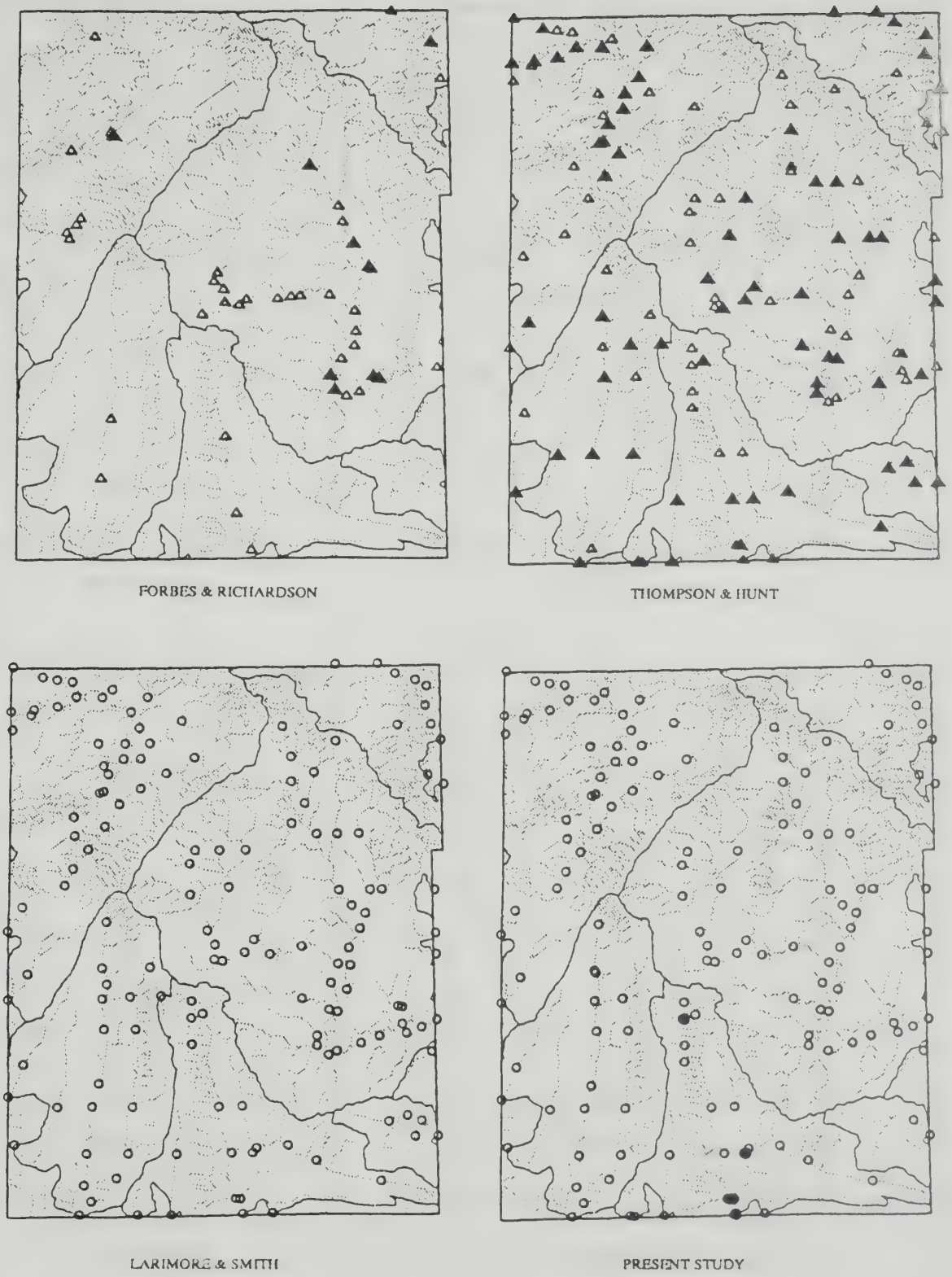


Fig A42. Closed circle -Presence, Open circle -absence of *Notropis fumeus*
Ribbon shiner (RBS) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of
Ribbon shiner and Redfin shiner (RBS/RDS)

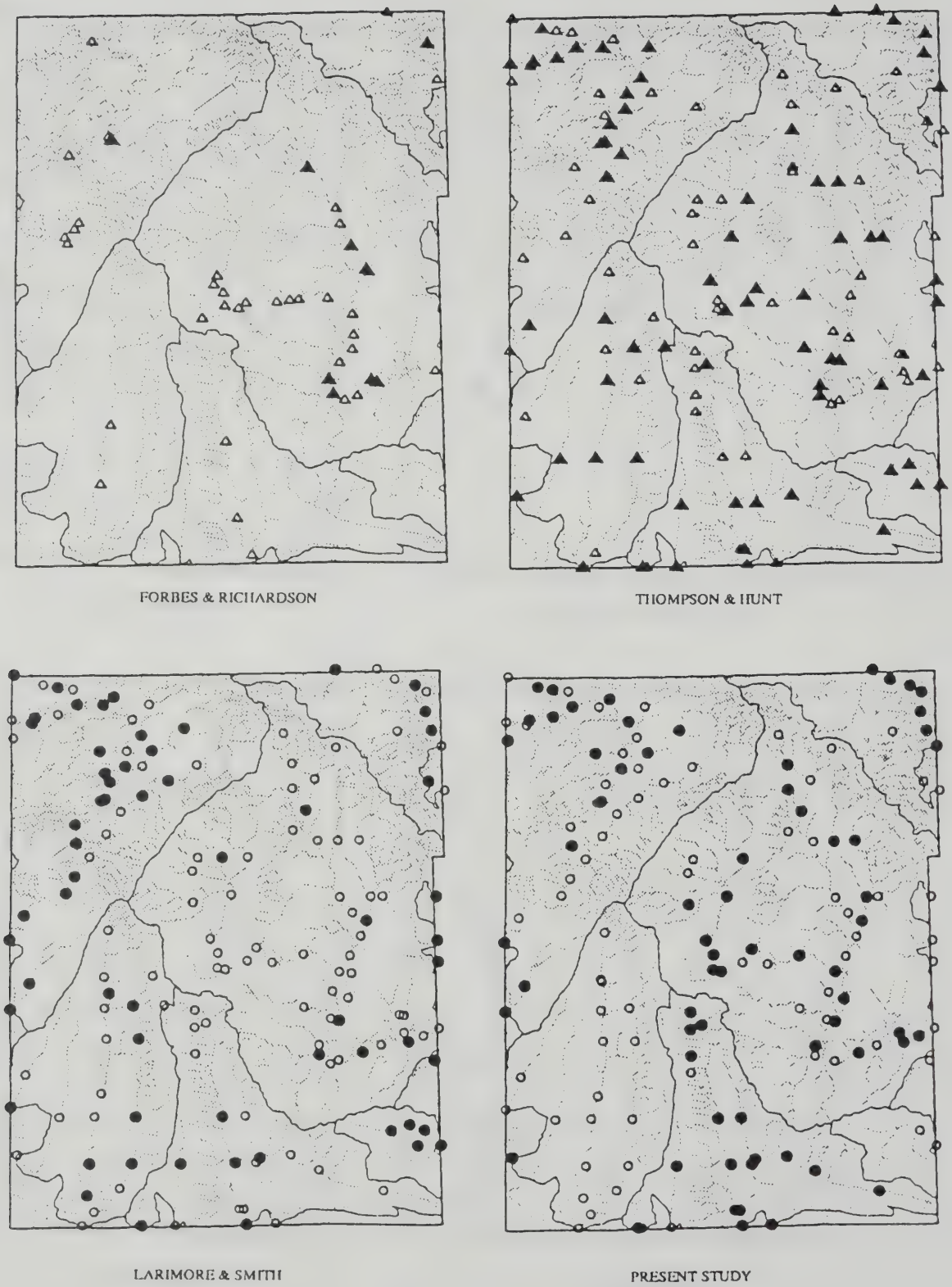


Fig A43. Closed circle -Presence, Open circle -absence of *Lythrurus umbratilis* Redfin shiner (RDS) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Ribbon shiner and Redfin shiner (RBS/RDS)

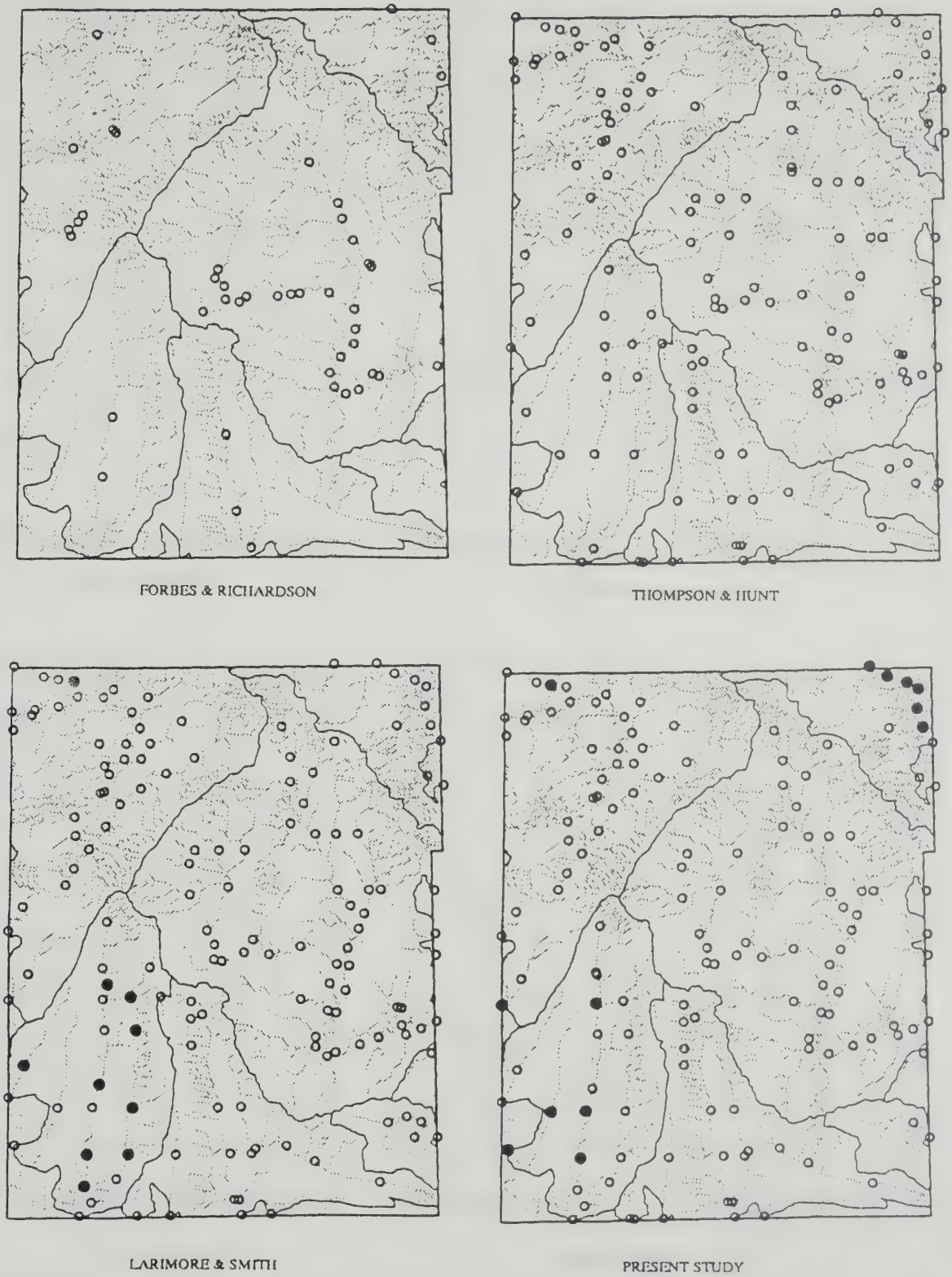
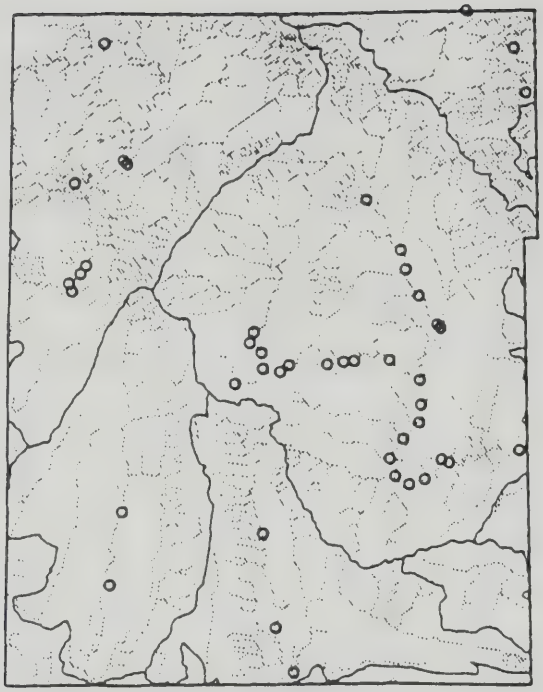


Fig A44. Closed circle -Presence, Open circle -absence of *Cyprinella lutrensis* Red shiner (RES) in Champaign County survey.



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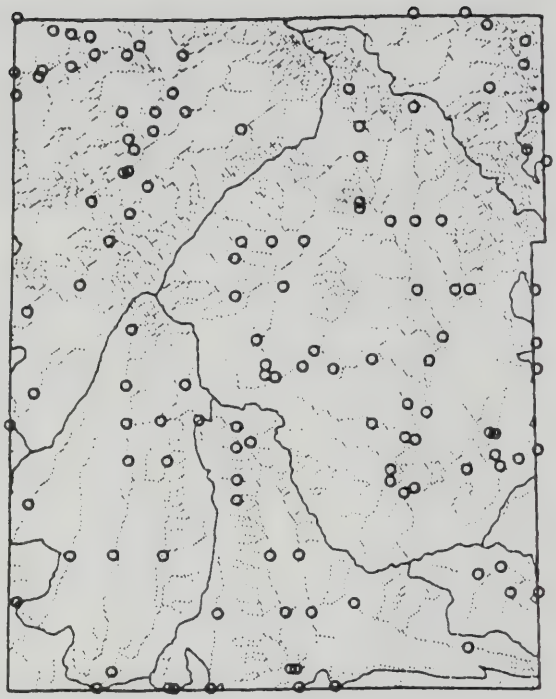
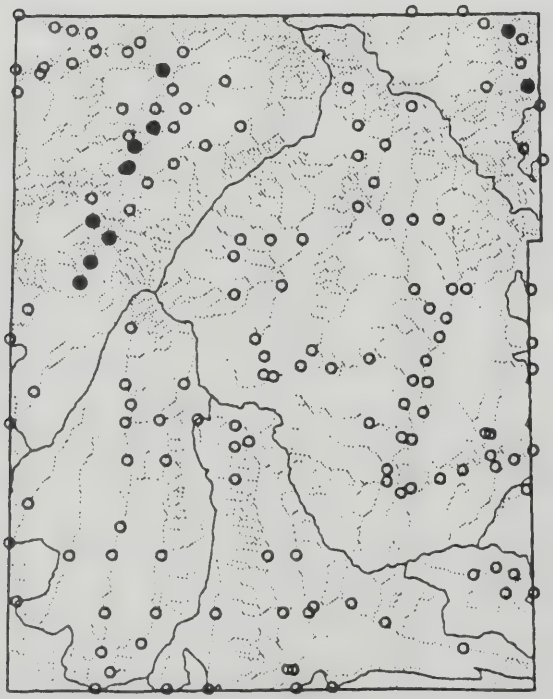
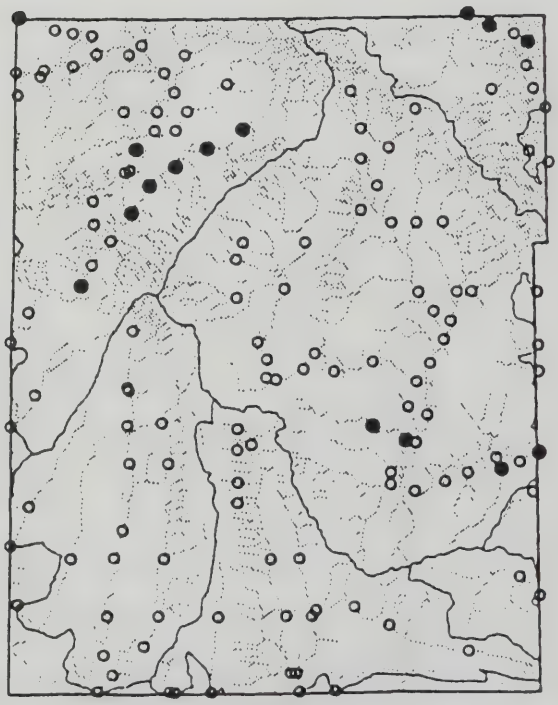


THOMPSON & HUNT

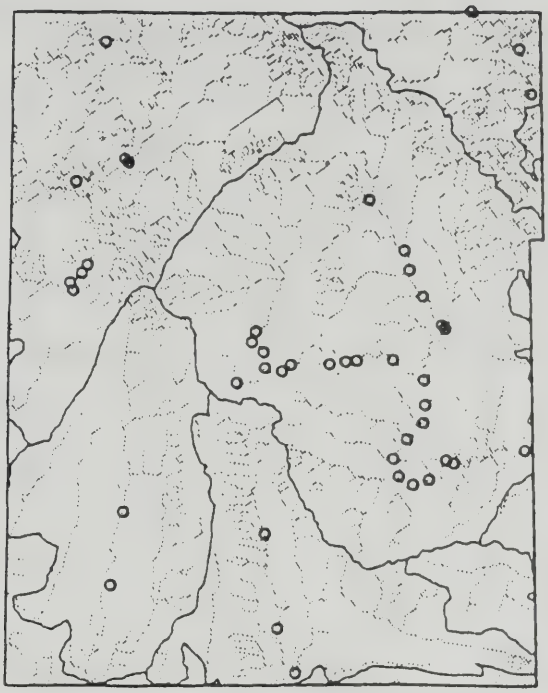


LARIMORE & SMITH

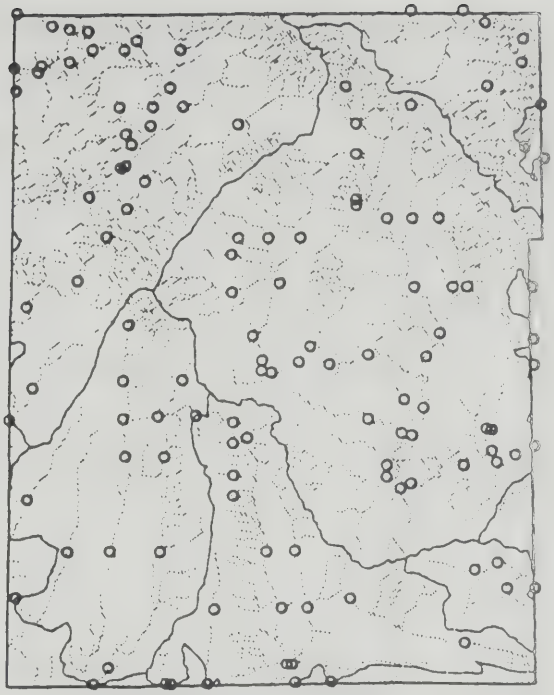


PRESENT STUDY

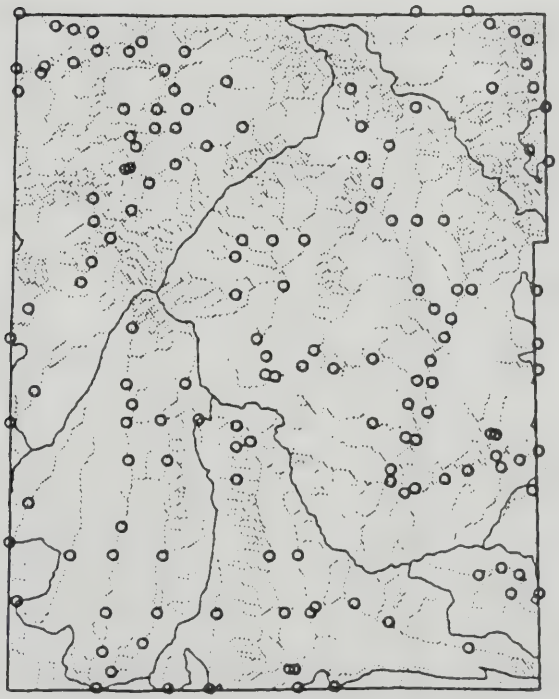
Fig A45. Closed circle -Presence, Open circle -absence of *Ambloplites rupestris* Rock bass (ROB) in Champaign County survey.



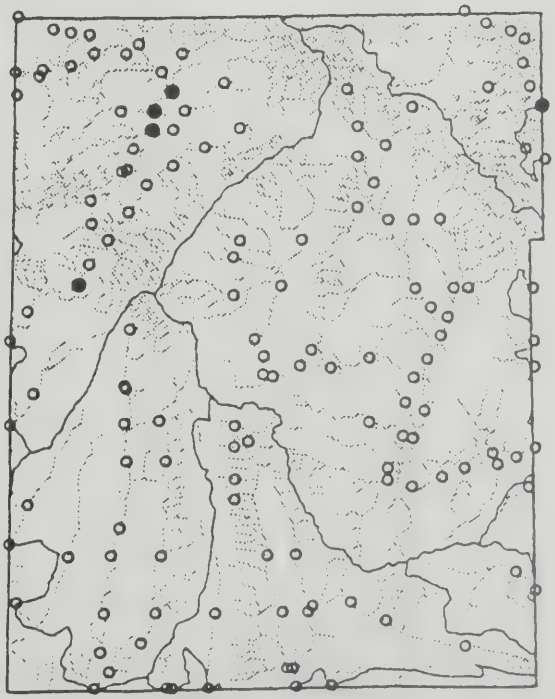
FORBES & RICHARDSON



THOMPSON & HUNT

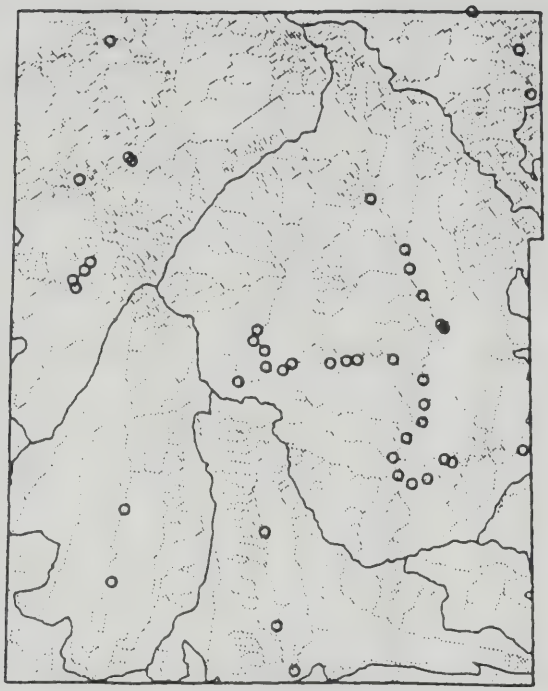


LARIMORE & SMITH

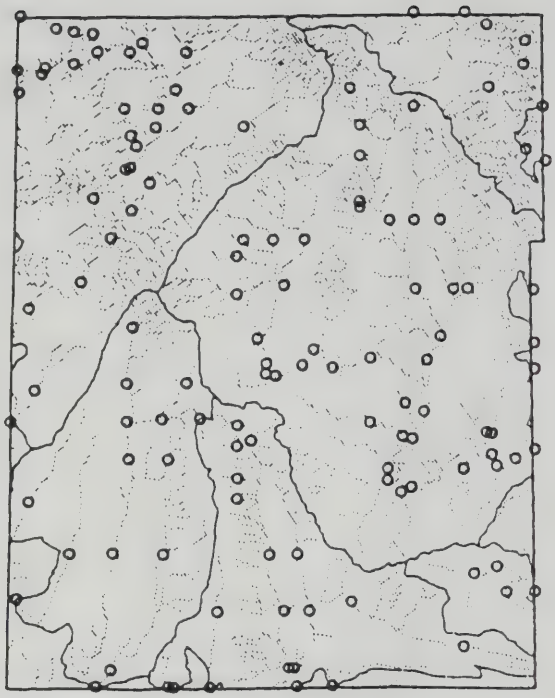


PRESENT STUDY

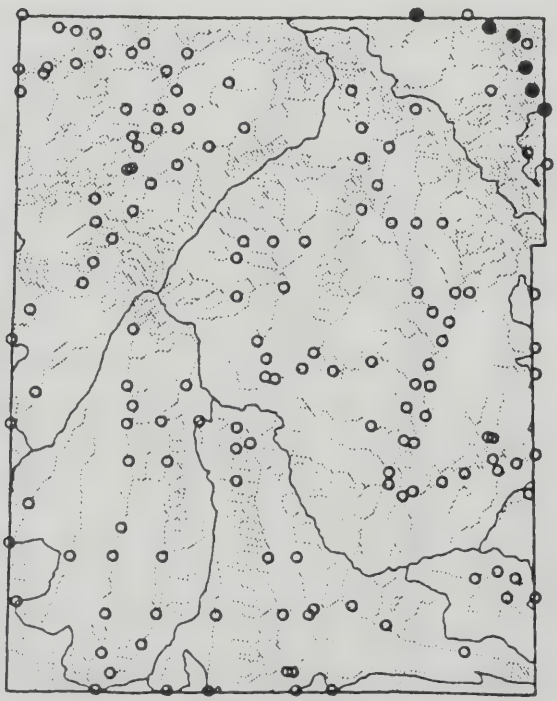
Fig A46. Closed circle -Presence, Open circle -absence of *Carpiodes carpio* River carpsucker (RVC) in Champaign County survey.



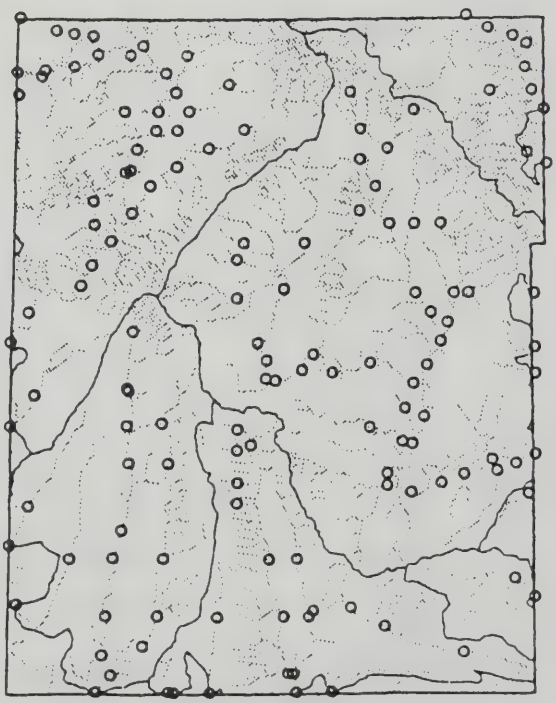
FORBES & RICHARDSON



THOMPSON & HUNT

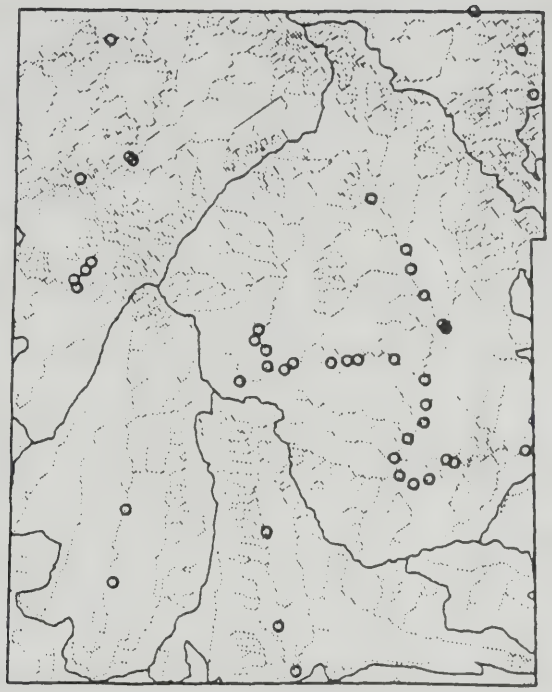


LARIMORE & SMITH

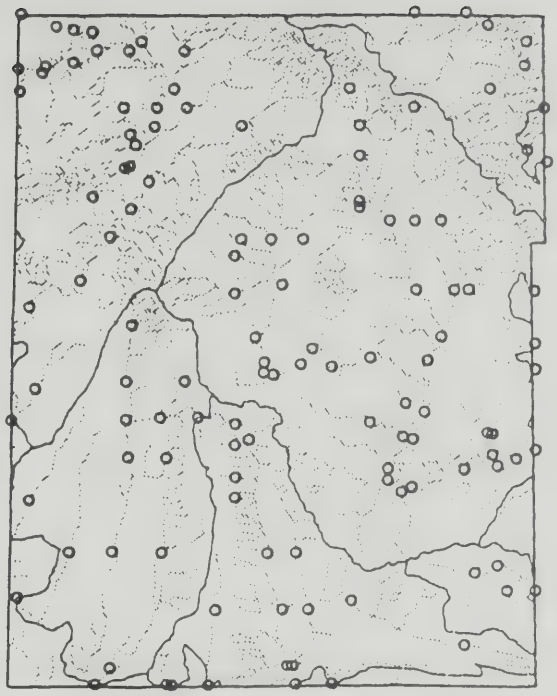


PRESENT STUDY

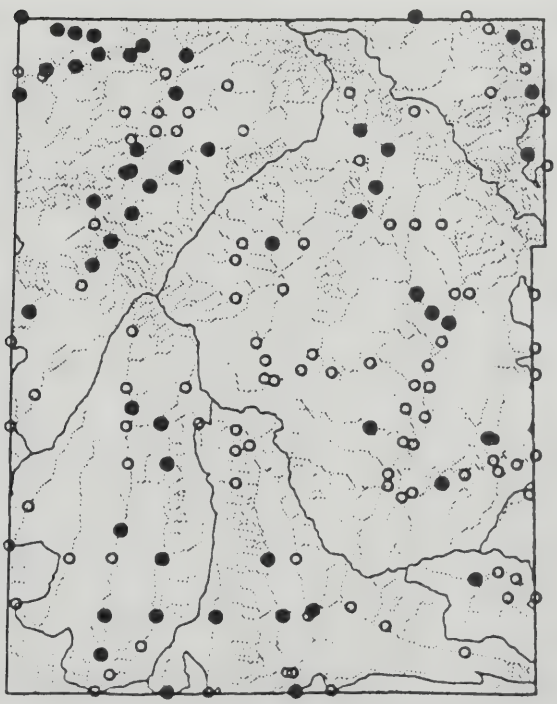
Fig A47. Closed circle -Presence, Open circle -absence of *Notropis rubellus* Rosyface shiner (RYS) in Champaign County survey.



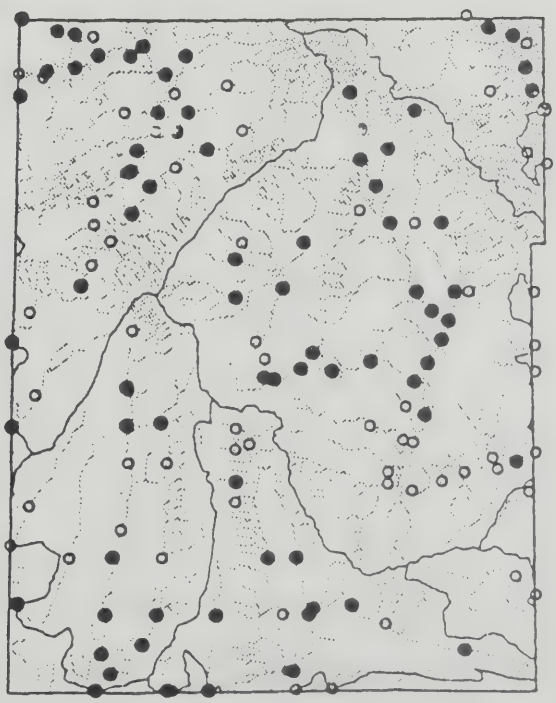
FORBES & RICHARDSON



THOMPSON & HUNT

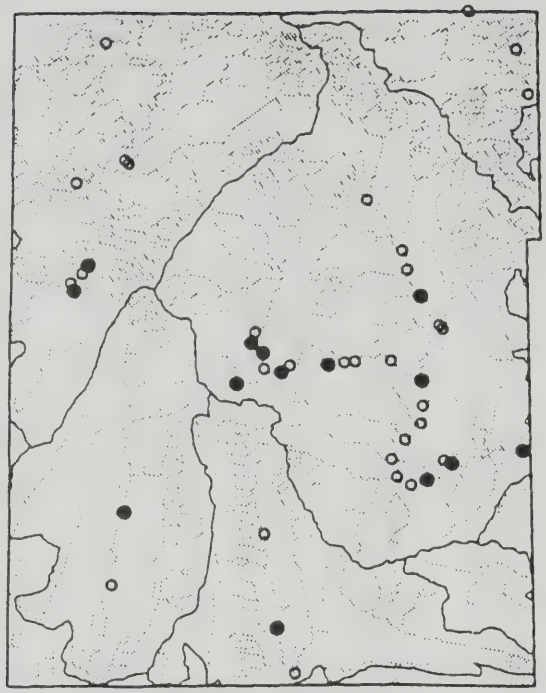


LARIMORE & SMITH

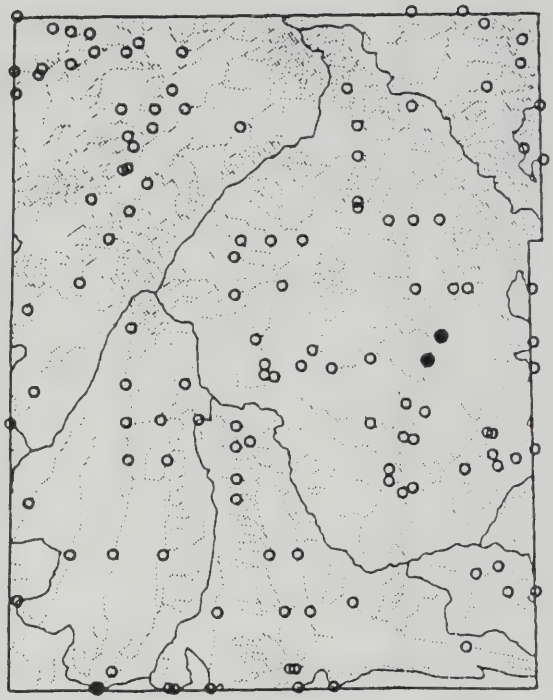


PRESENT STUDY

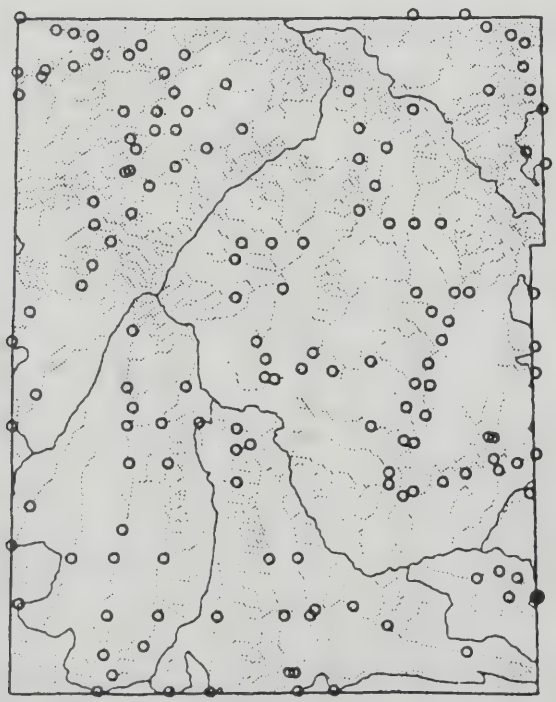
Fig A48. Closed circle -Presence, Open circle -absence of *Notropis ludibundus* Sand shiner (SAS) in Champaign County survey.



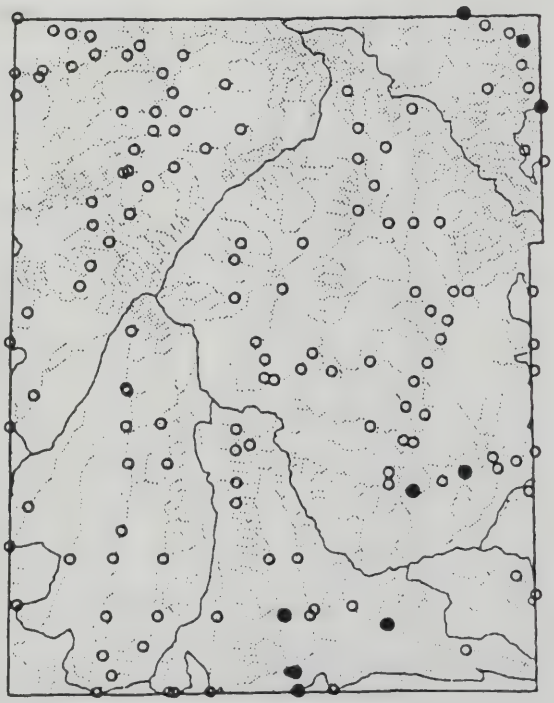
FORBES & RICHARDSON



THOMPSON & HUNT

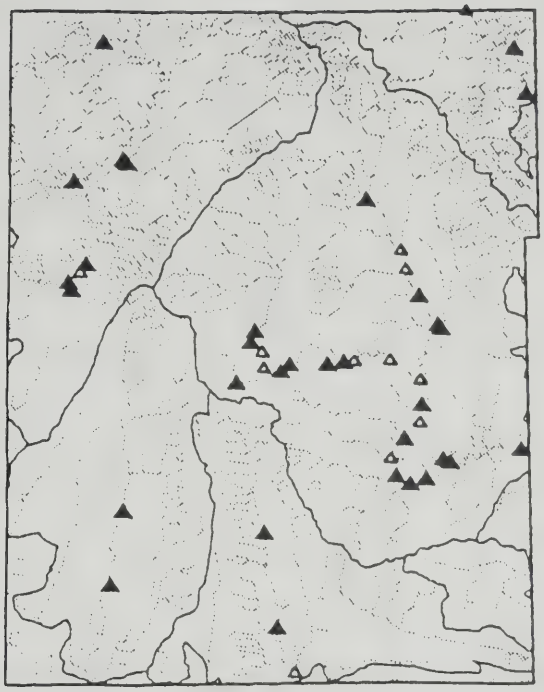


LARIMORE & SMITH



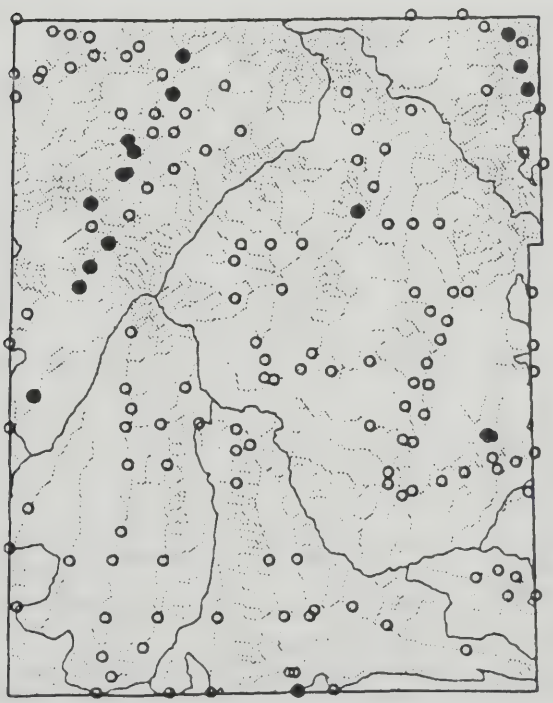
PRESENT STUDY

Fig A49. Closed circle -Presence, Open circle -absence of *Minytrema melanops* Spotted sucker (SDS) in Champaign County survey.

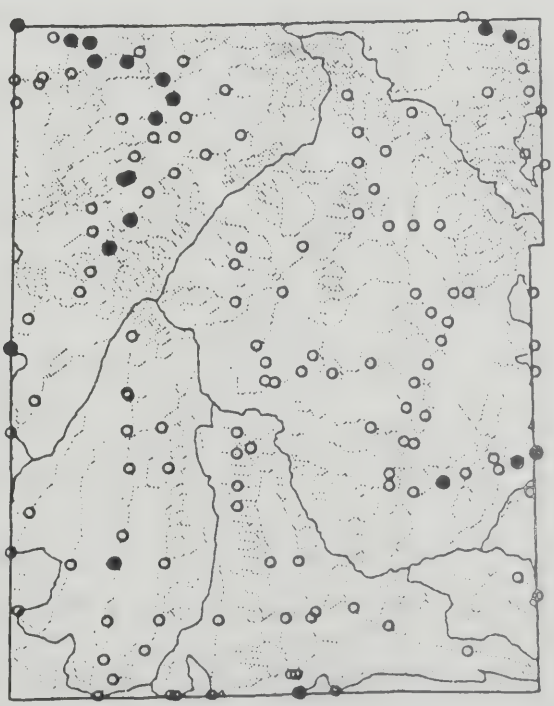


FORBES & RICHARDSON

THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A50. Closed circle -Presence, Open circle -absence of *Notropis whipplei* Steelcolor shiner (SES) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Steelcolor shiner and Spotfin shiner (SES/SFS)

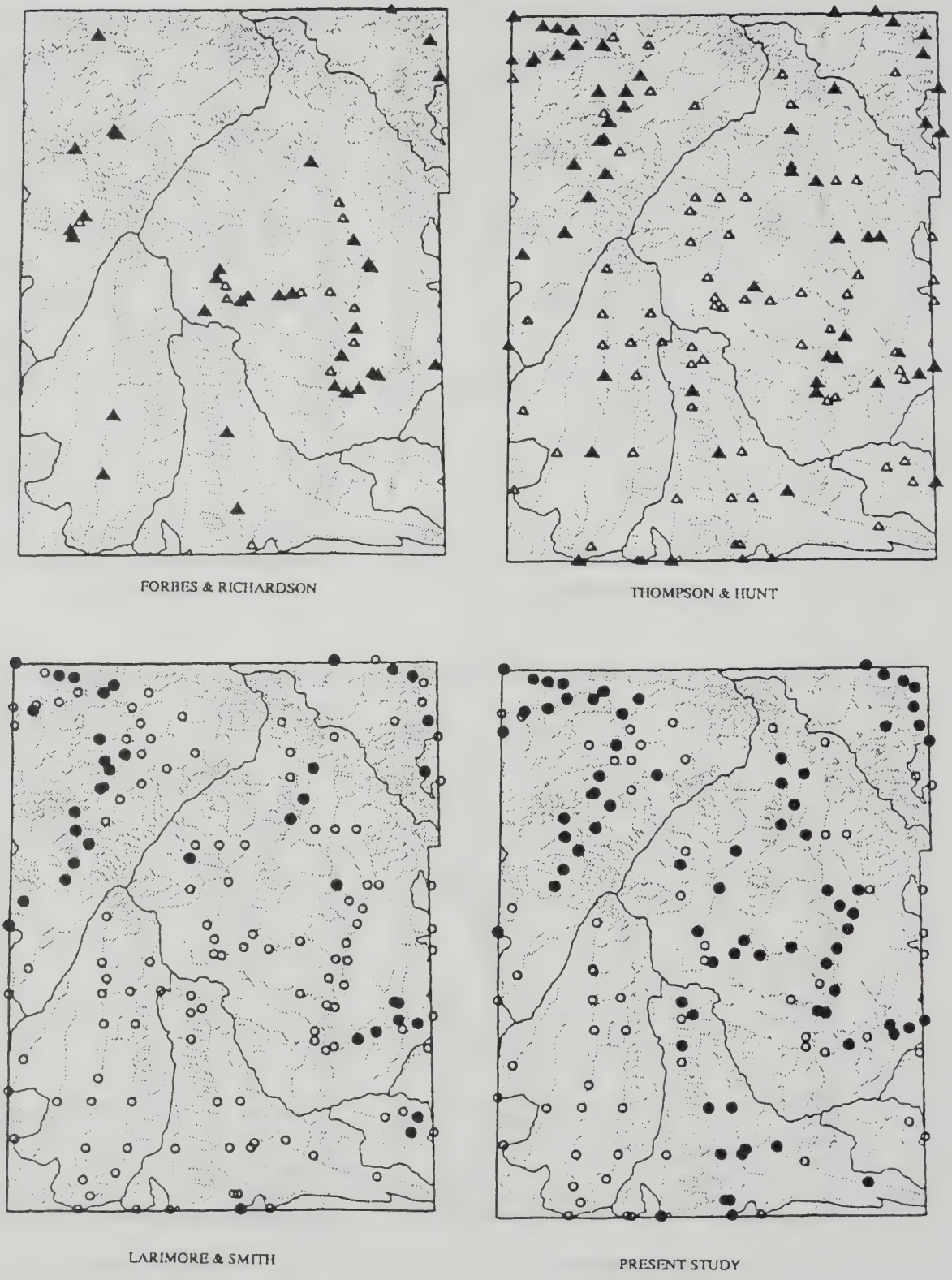


Fig A51. Closed circle -Presence, Open circle -absence of *Cyprinella spiloptera* Spotfin shiner (SFS) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Steelcolor shiner and Spotfin shiner (SES/SFS)

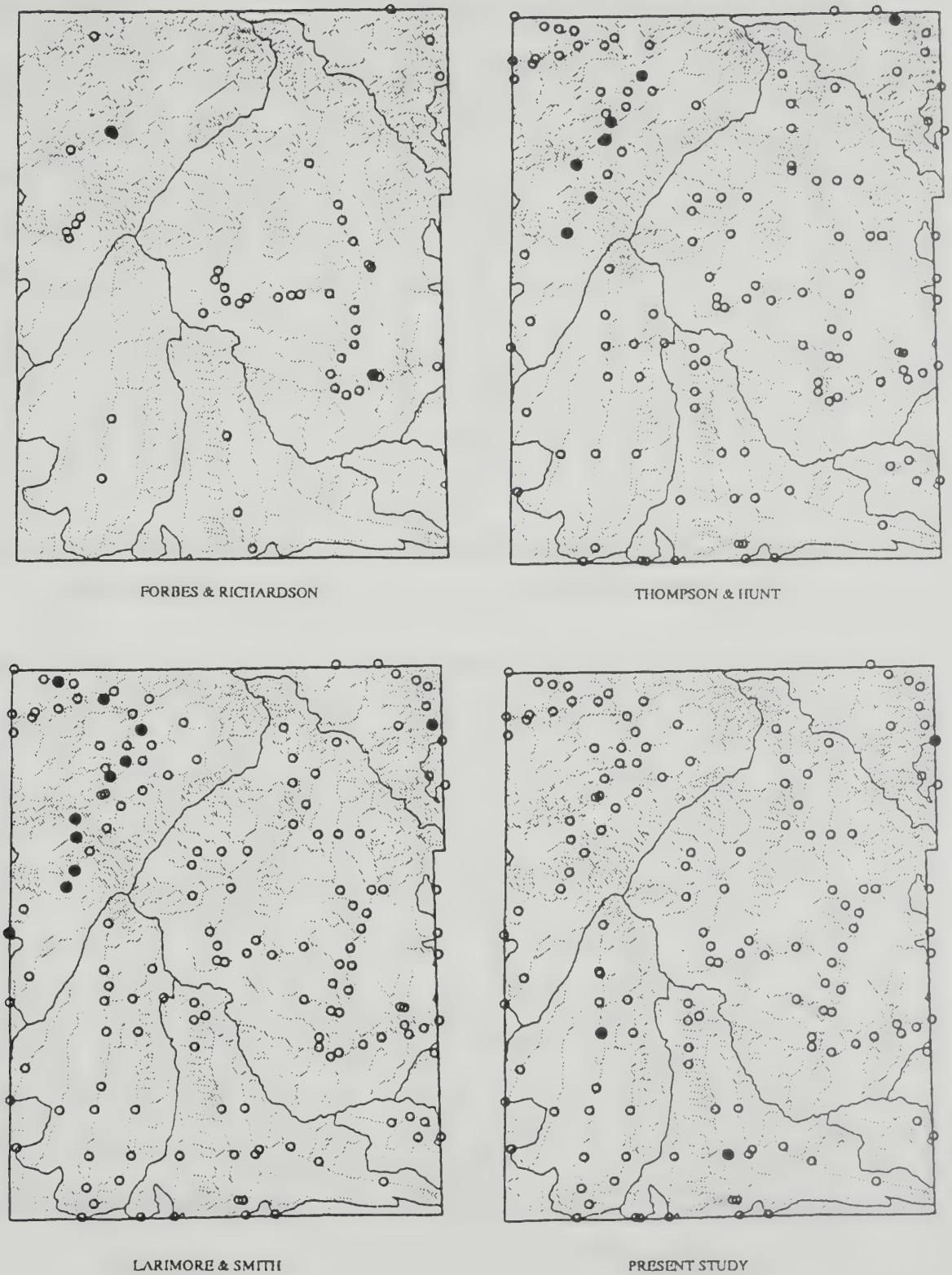
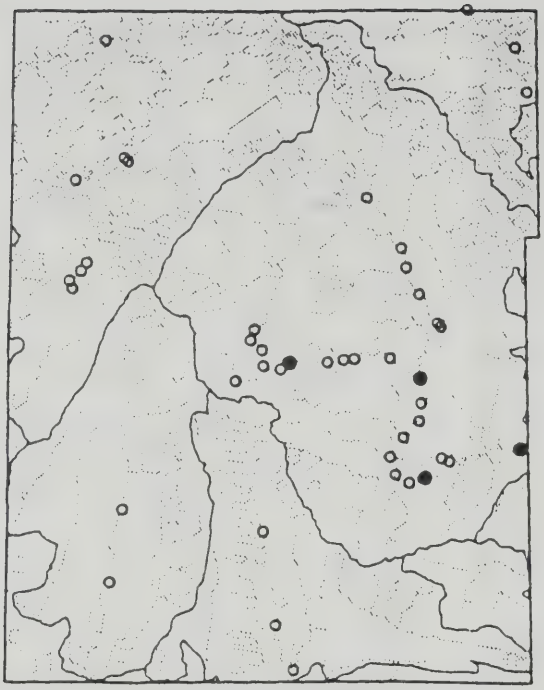
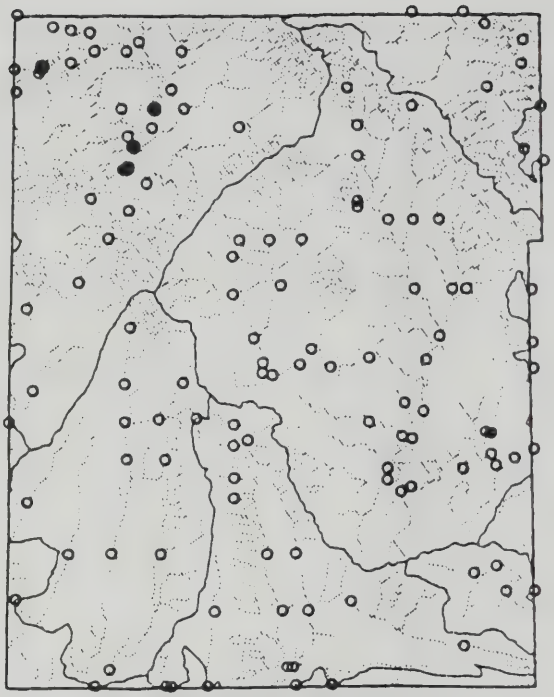


Fig A52. Closed circle -Presence, Open circle -absence of *Percina phoxocephala* Slenderhead darter (SHD) in Champaign County survey.



FORBES & RICHARDSON



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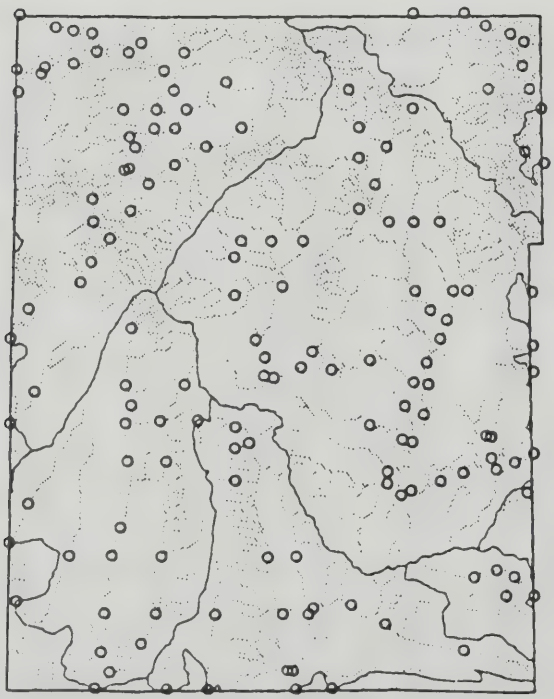

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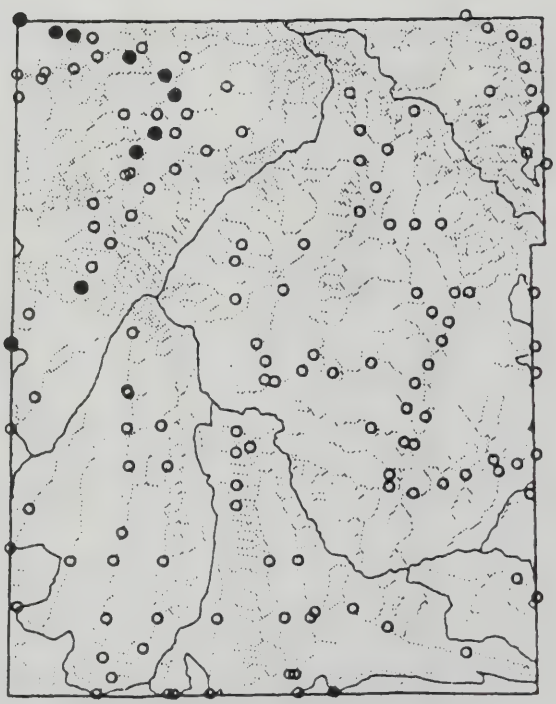


PRESENT STUDY

Fig A53. Closed circle -Presence, Open circle -absence of *Moxostoma macrolepidotum* Shorthead redhorse (SHR) in Champaign County survey.

Fig A54. Closed circle -Presence, Open circle -absence of *Ericymba buccata* Silverjaw minnow (SJM) in Champaign County survey.

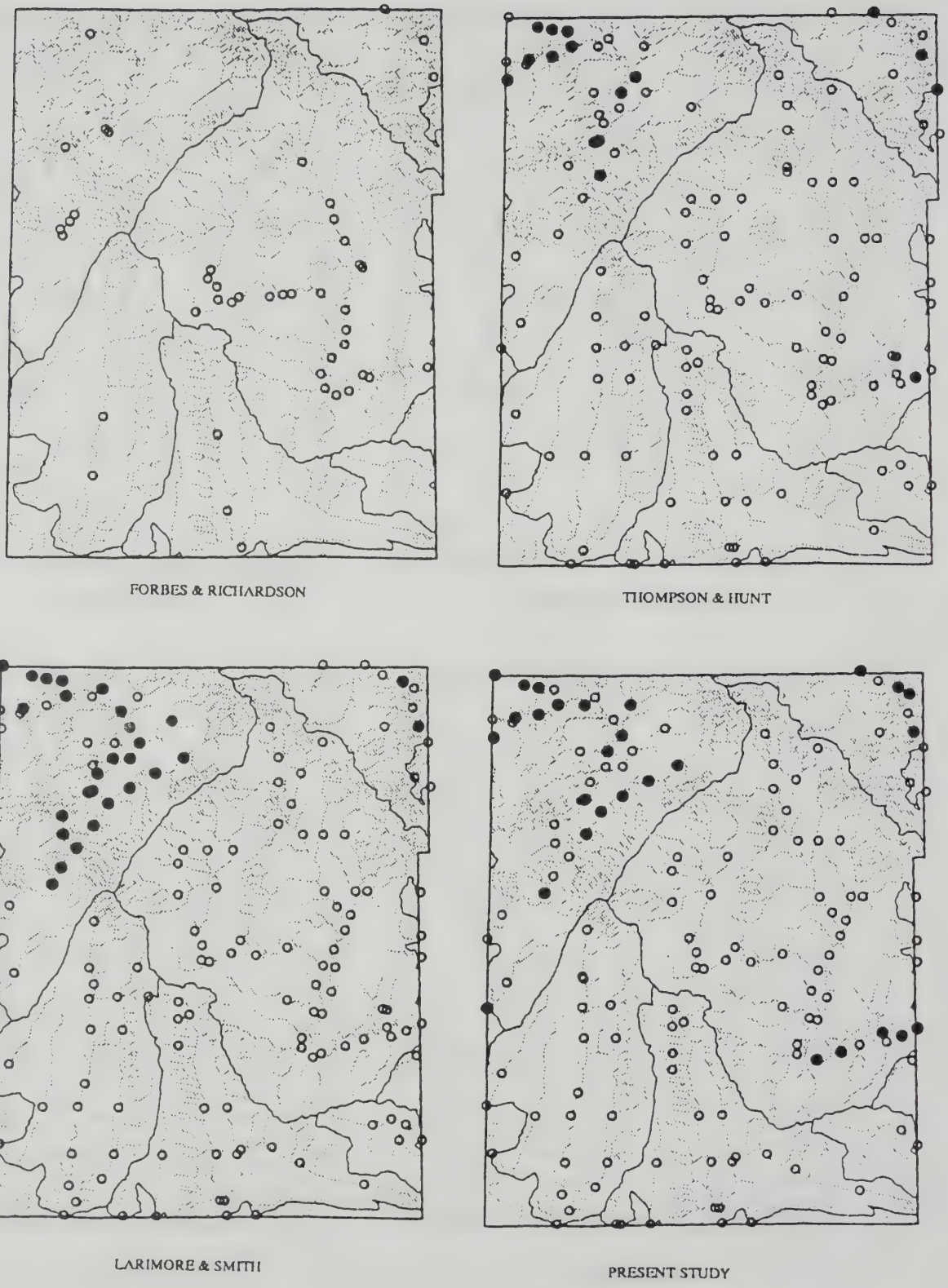


Fig A55. Closed circle -Presence, Open circle -absence of *Micropterus dolomieui* Smallmouth bass (SMB) in Champaign County survey.

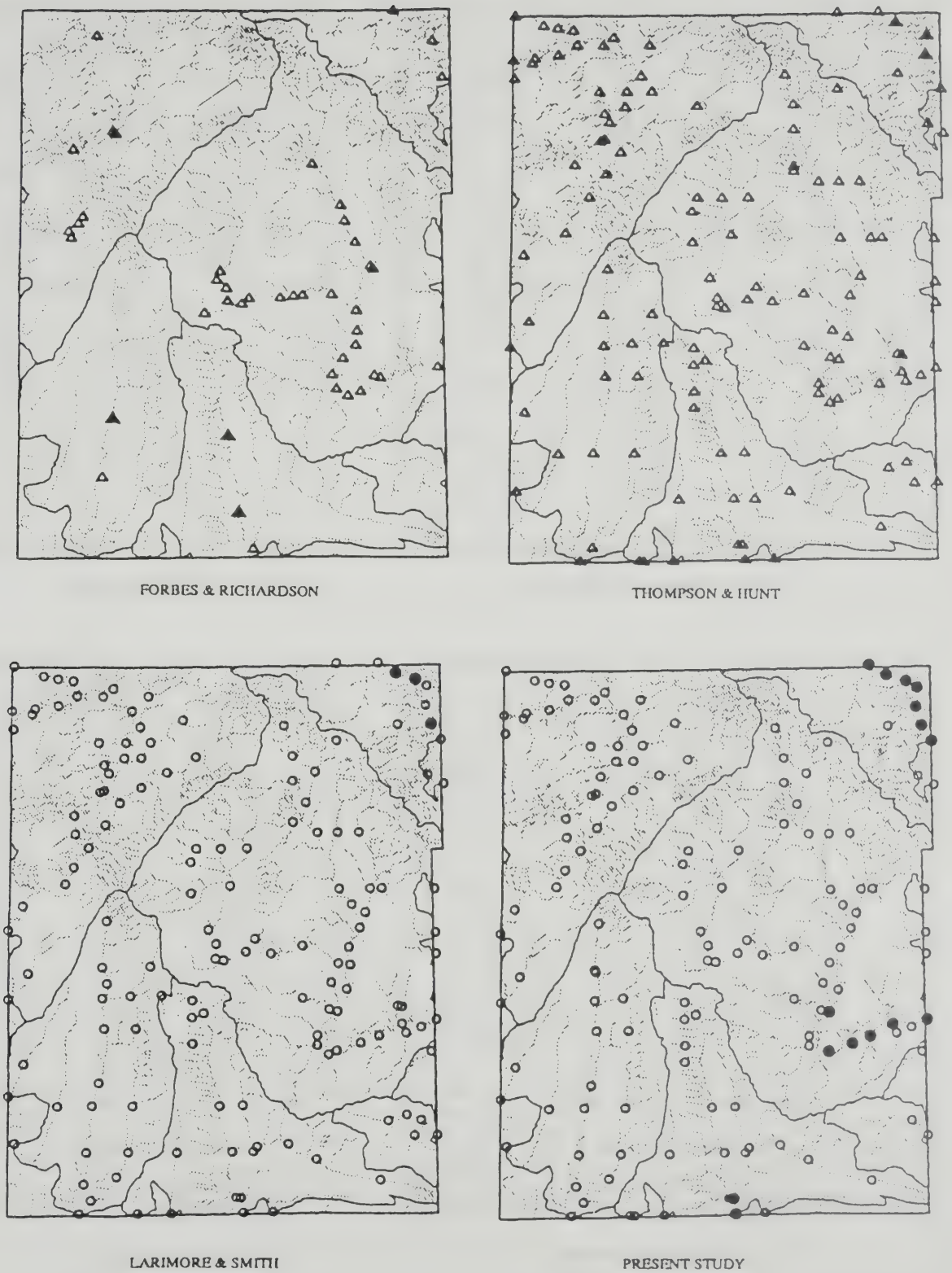


Fig A56. Closed circle -Presence, Open circle -absence of *Micropterus punctulatus* Spotted bass (SPB) in Champaign County survey.
Closed triangles -Presence, Open triangles -absence of Largemouth bass and Spotted bass (LMB/SPB)

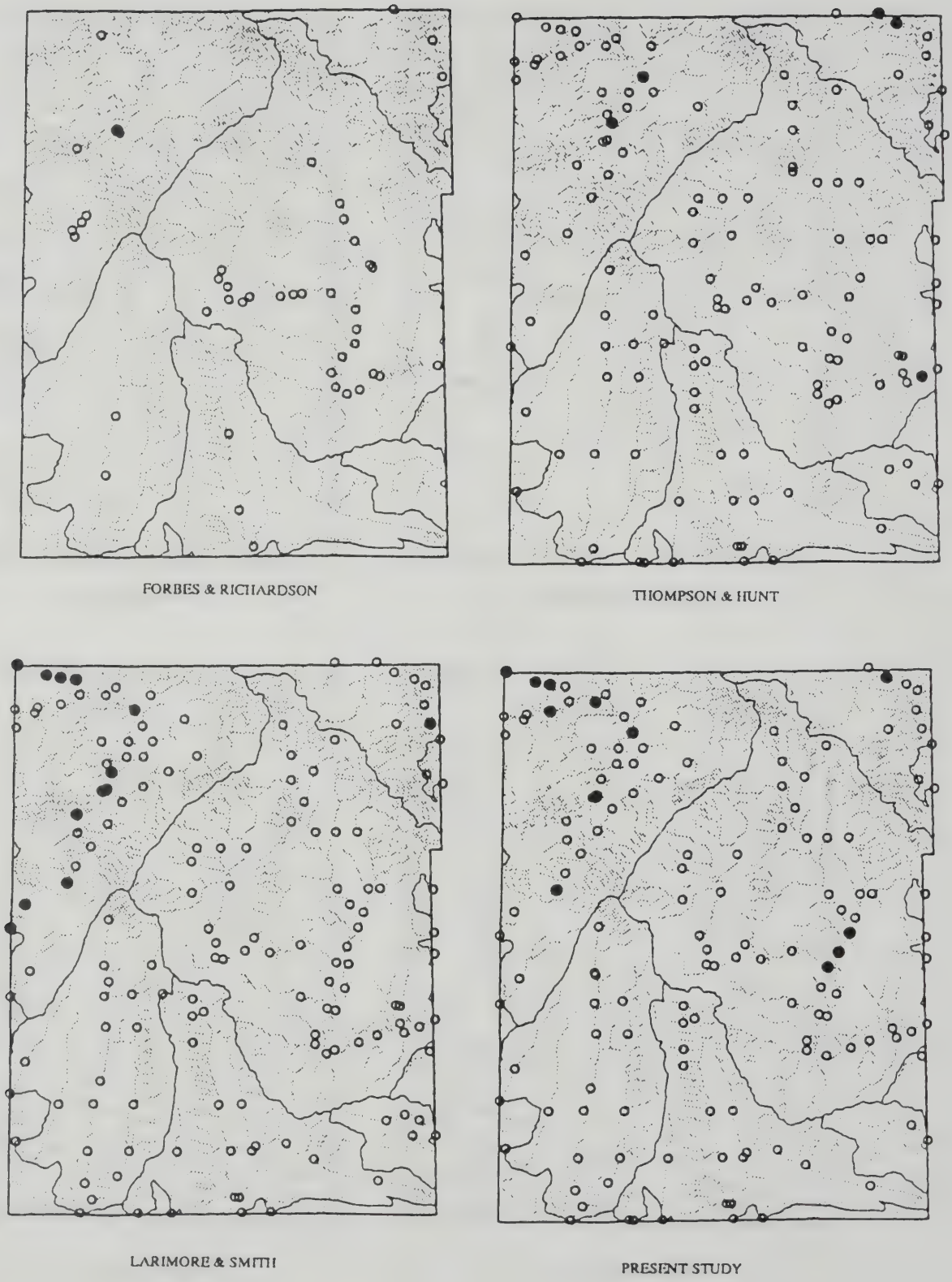
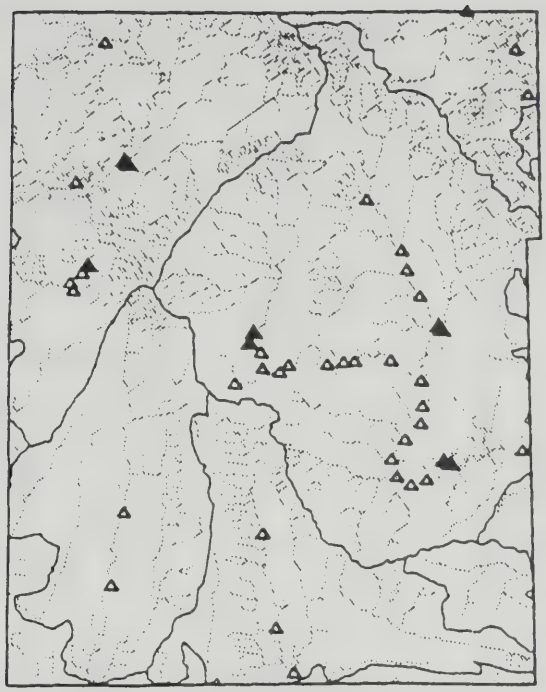


Fig A57. Closed circle -Presence, Open circle -absence of *Noturus flavus* Stonecat (STC) in Champaign County survey.



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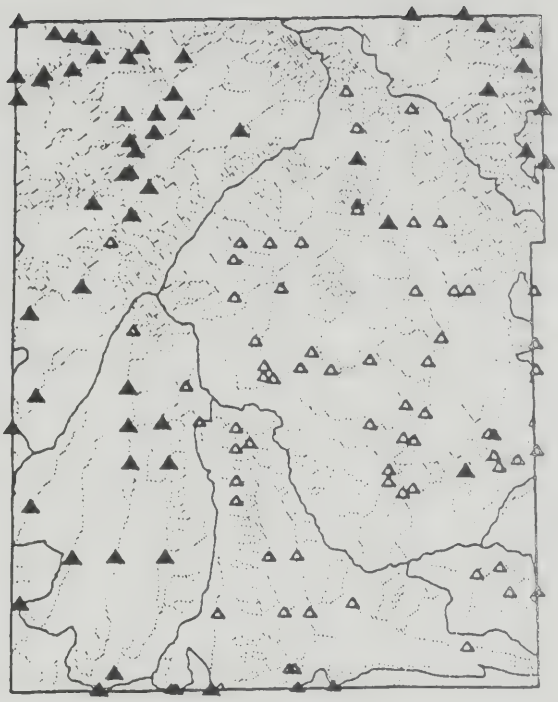
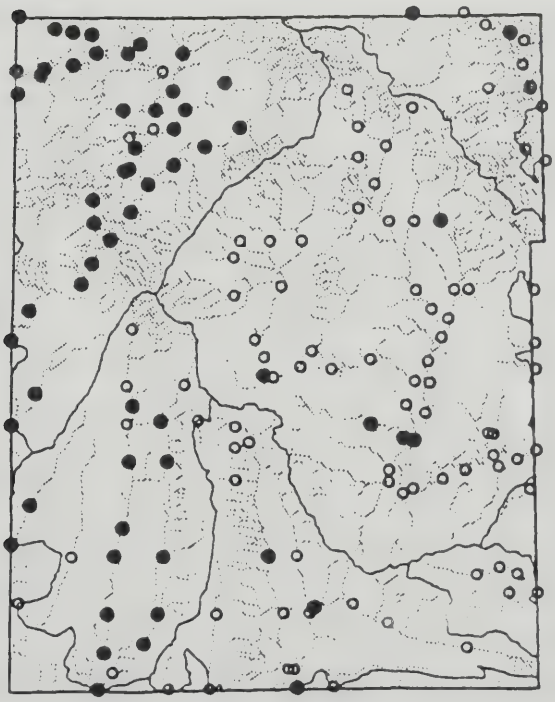
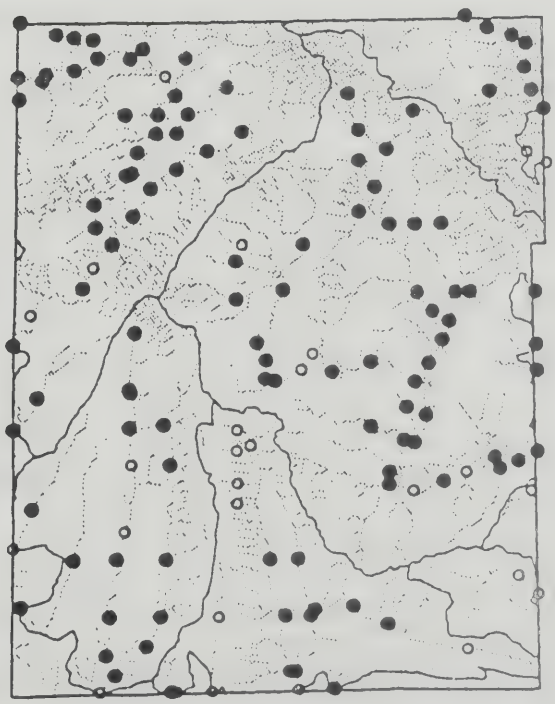


THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A58. Closed circle -Presence, Open circle -absence of *Luxilus chrysocephalus* Striped shiner (STS) in Champaign County survey.
Closed triangle -Presence, Open triangle -absence of Striped shiner and Common shiner (STS/CMS)

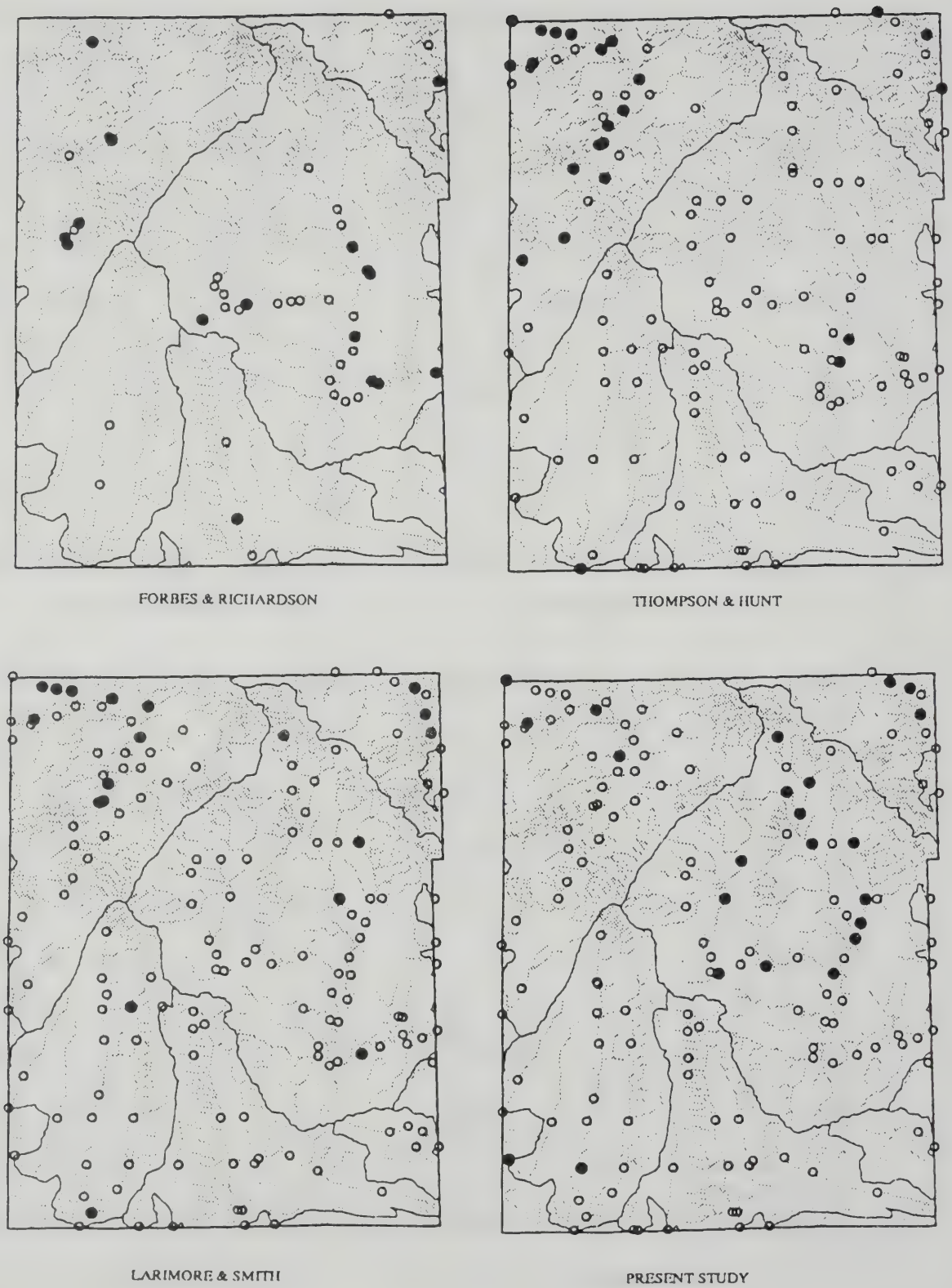
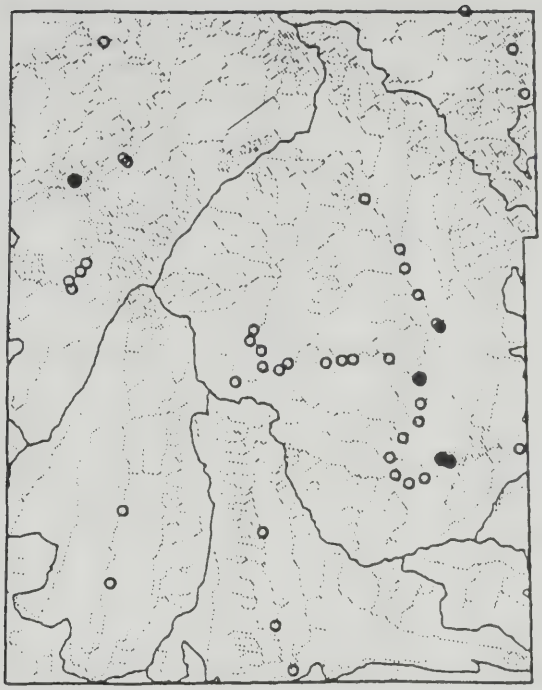
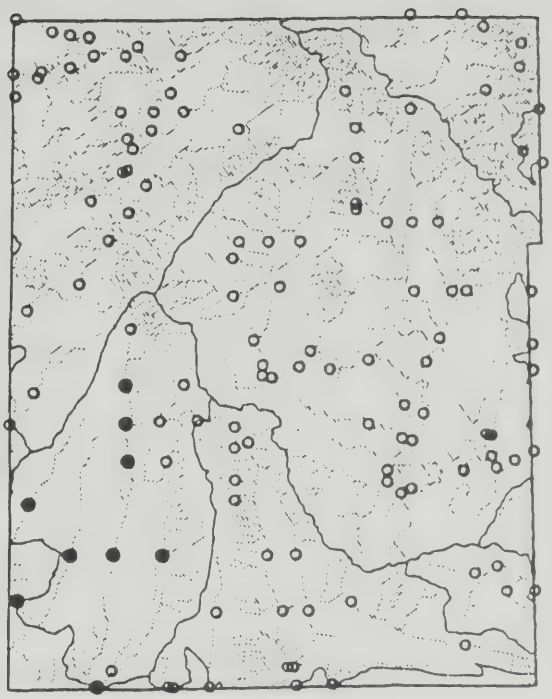


Fig A59. Closed circle -Presence, Open circle -absence of *Phenacobius mirabilis* Suckermouth minnow (SUM) in Champaign County survey.



FORBES & RICHARDSON



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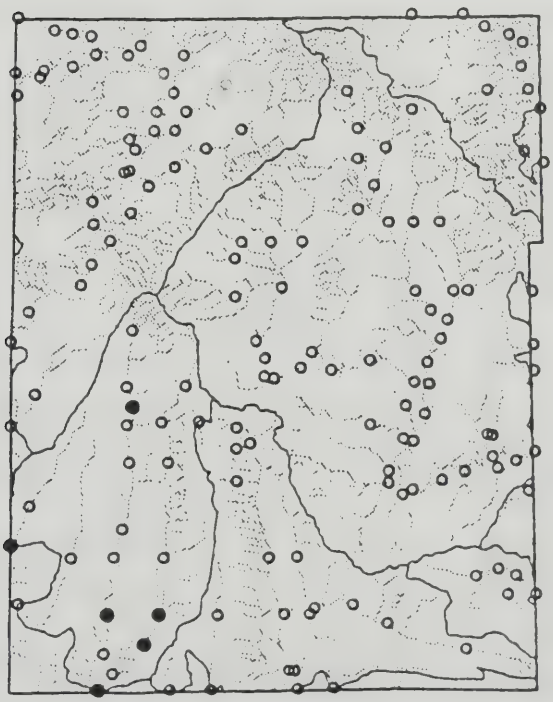
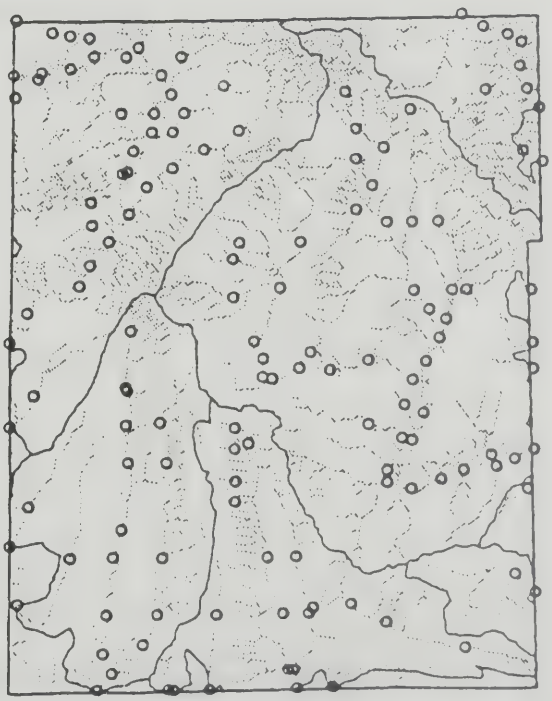


LARIMORE & SMITH



PRESENT STUDY

Fig A60. Closed circle -Presence, Open circle -absence of *Hybognathus nuchalis* Silvery minnow (SVM) in Champaign County survey.

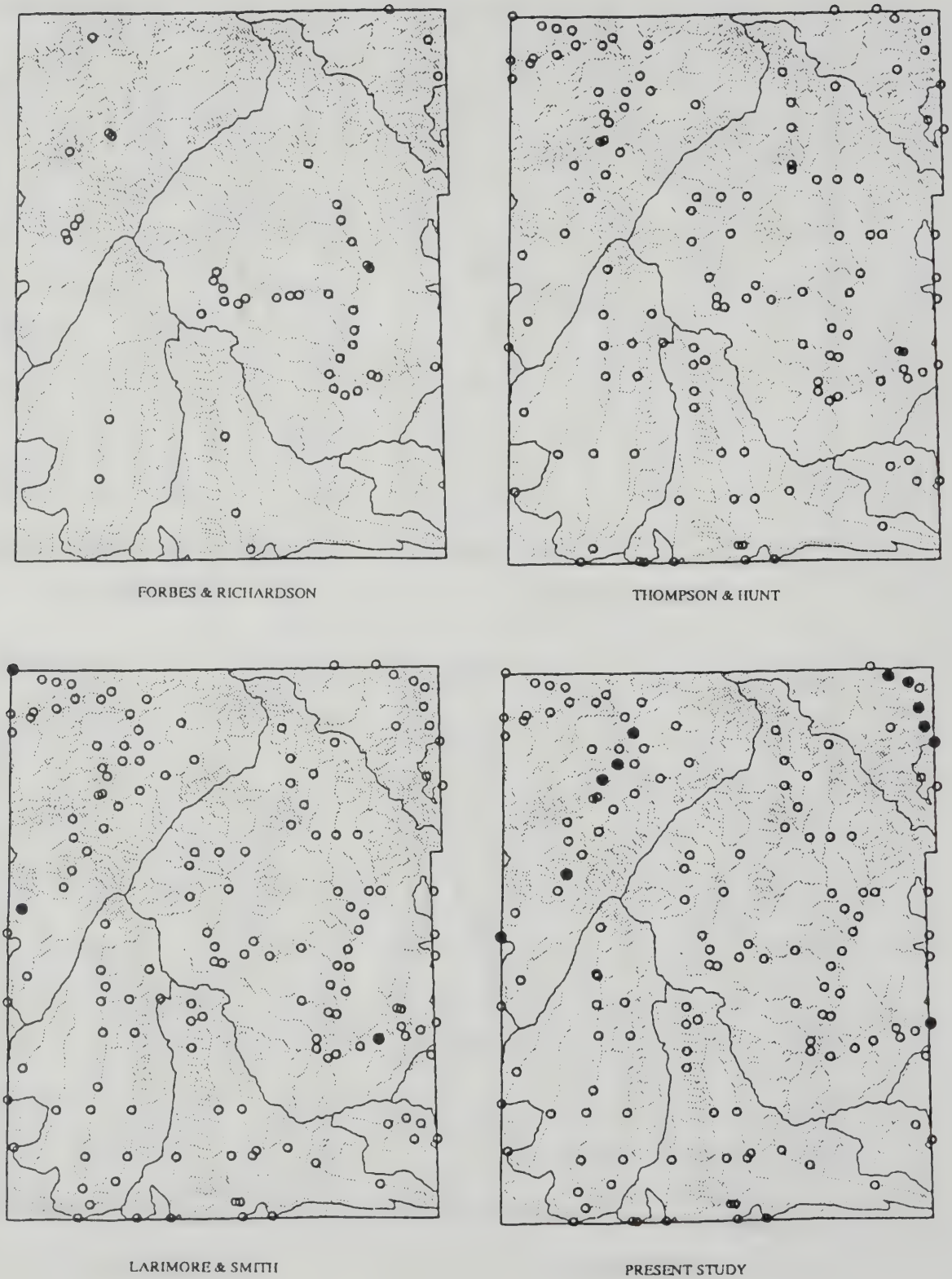


Fig A61. Closed circle -Presence, Open circle -absence of *Moxostoma anisurum* Silver redhorse (SVR) in Champaign County survey.

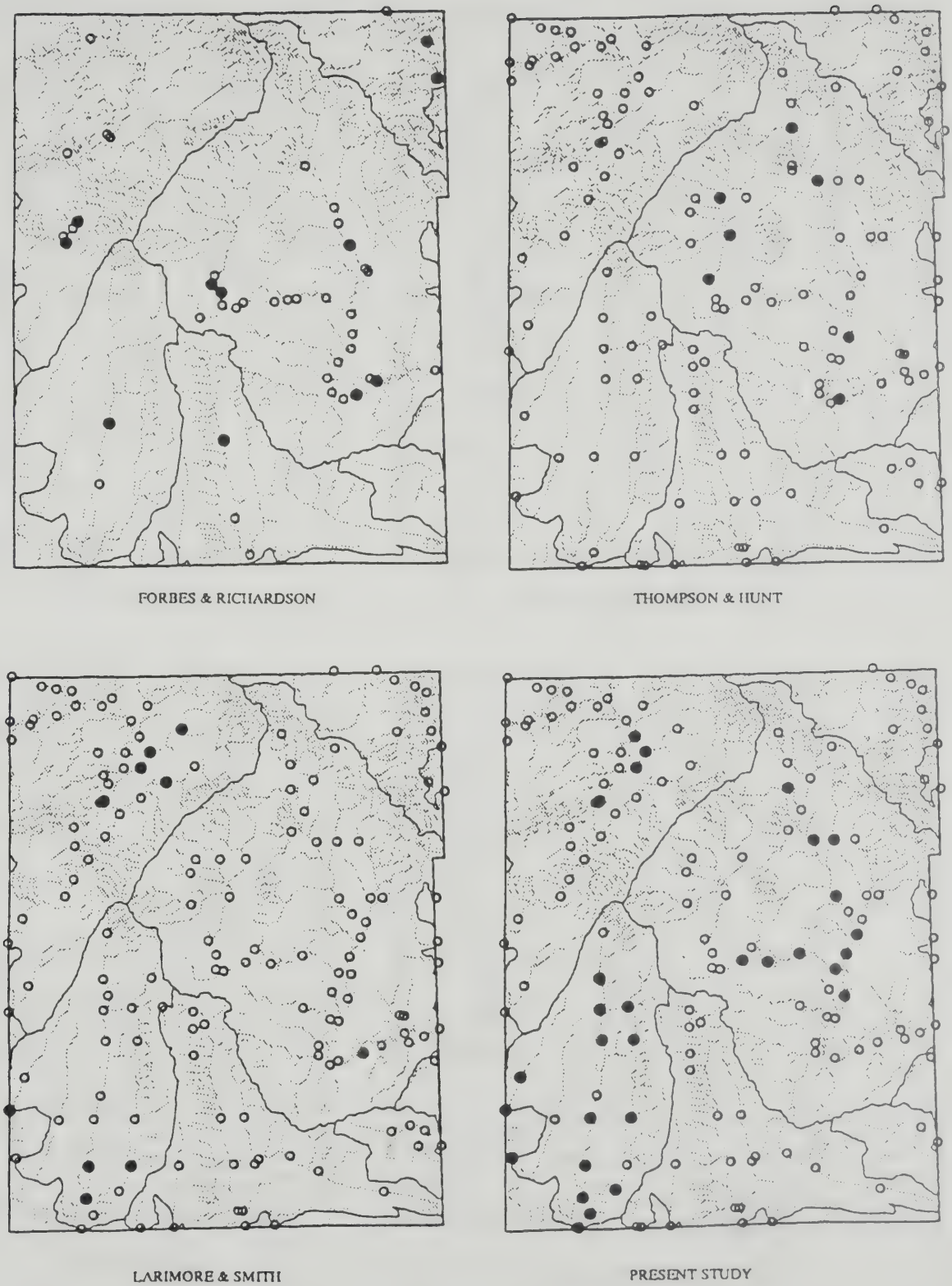


Fig A62. Closed circle -Presence, Open circle -absence of *Noturus gyrinus* Tadpole madtom (TPM) in Champaign County survey.

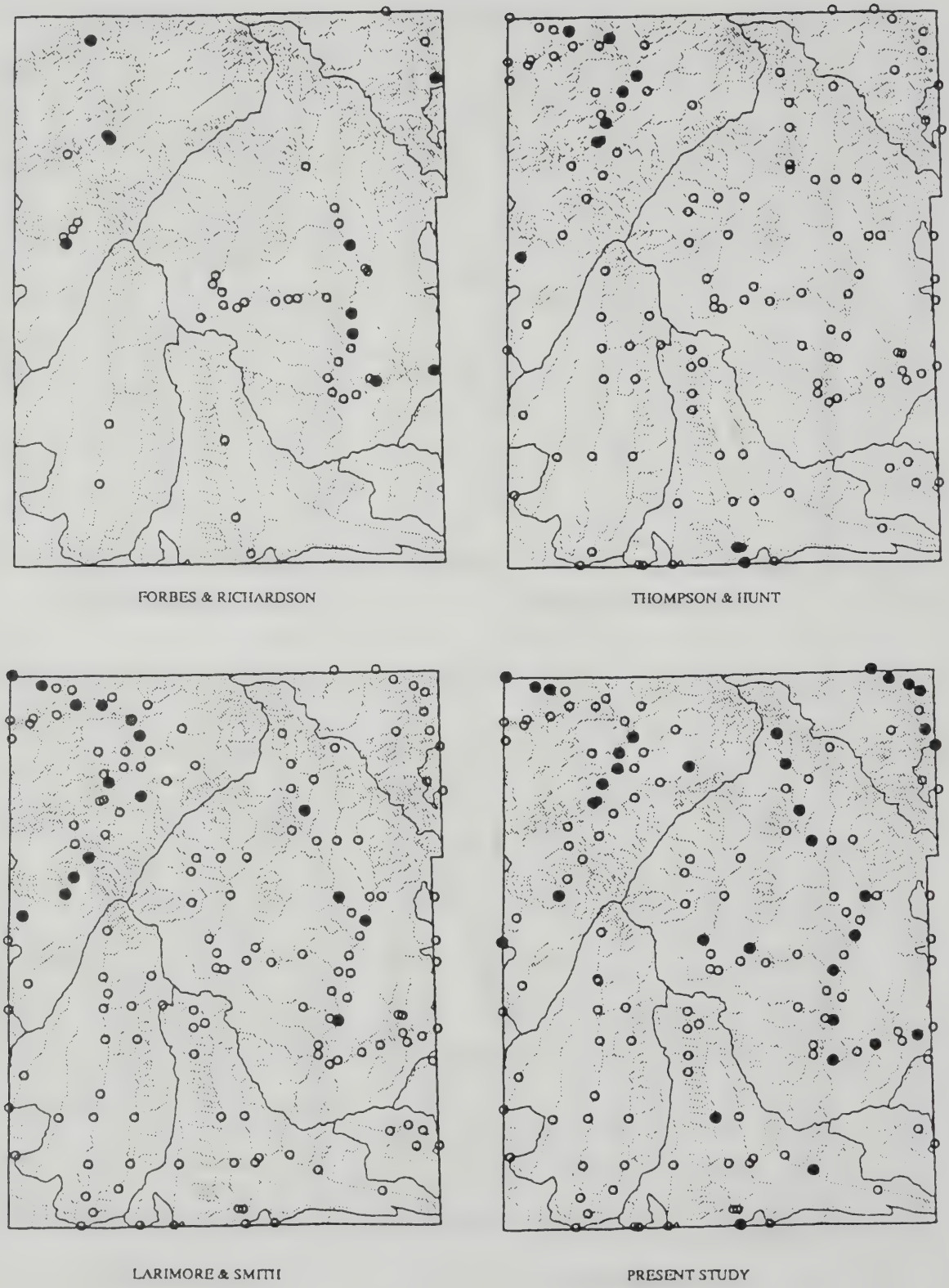


Fig A63. Closed circle -Presence, Open circle -absence of *Carpiodes cyprinus* Quillback (ULL) in Champaign County survey.

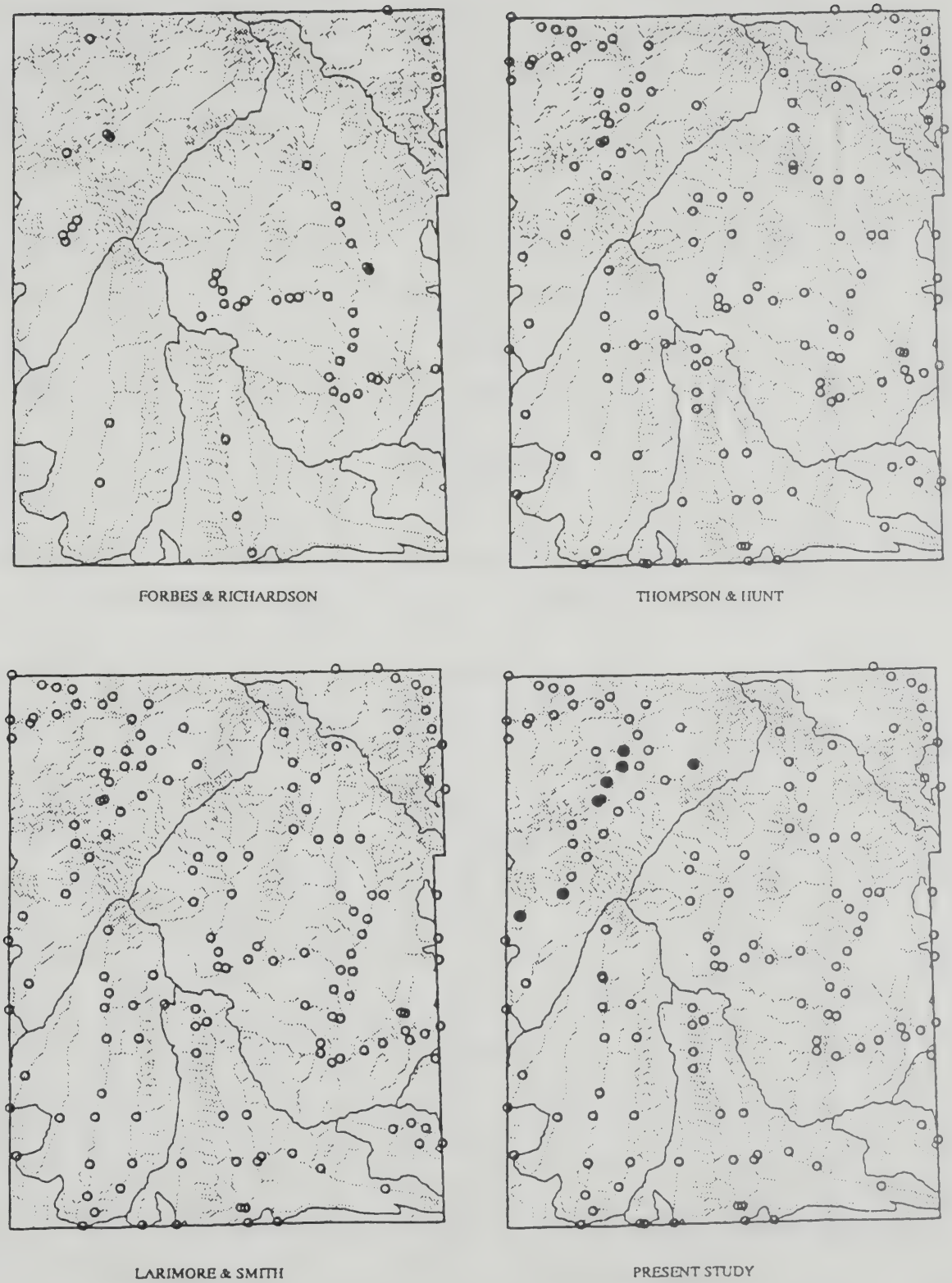
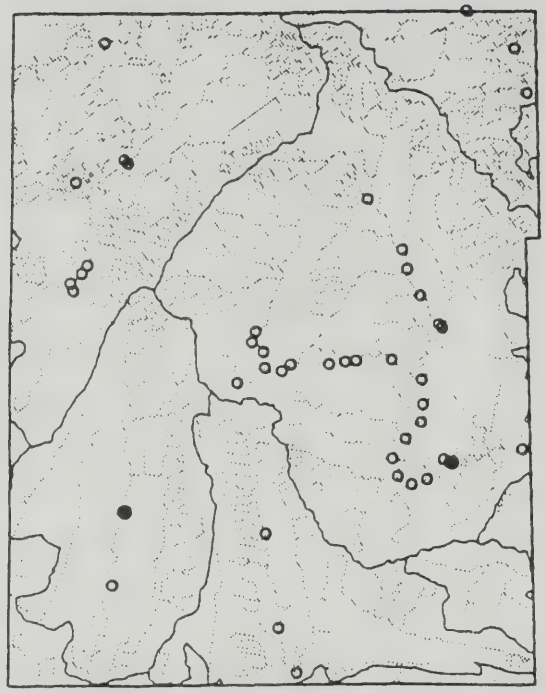
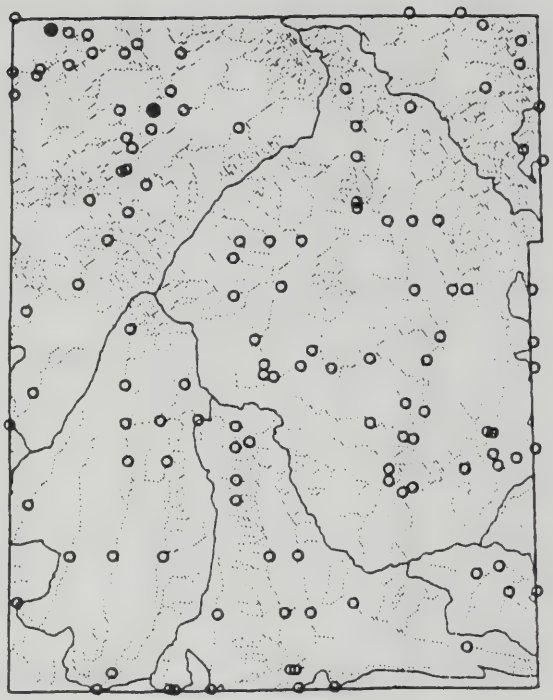


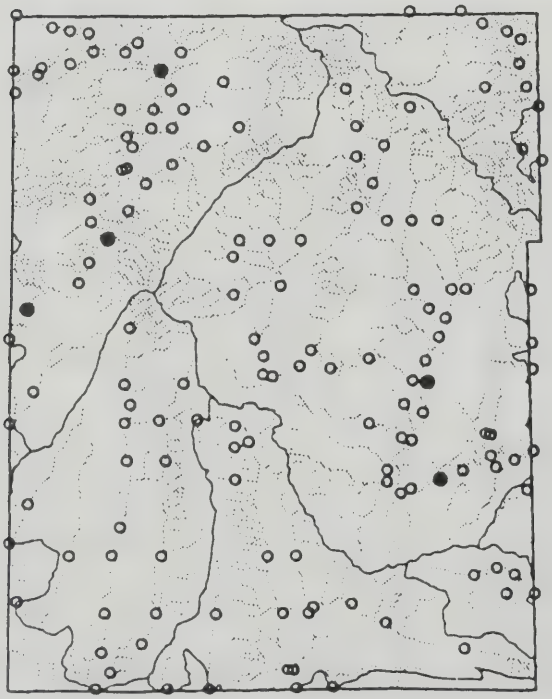
Fig A64. Closed circle -Presence, Open circle -absence of *Morone chrysops* White bass (WHB) in Champaign County survey.



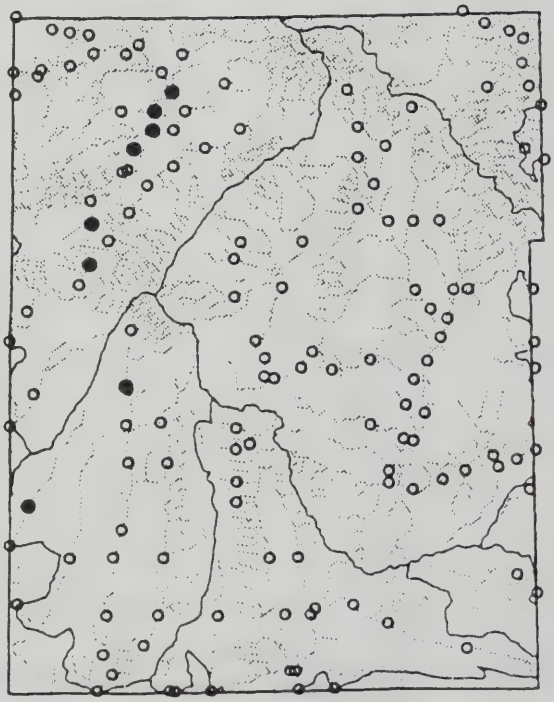
FORBES & RICHARDSON



THOMPSON & HUNT



LARIMORE & SMITH



PRESENT STUDY

Fig A65. Closed circle -Presence, Open circle -absence of *Pomoxis annularis* White crappie (WHC) in Champaign County survey.

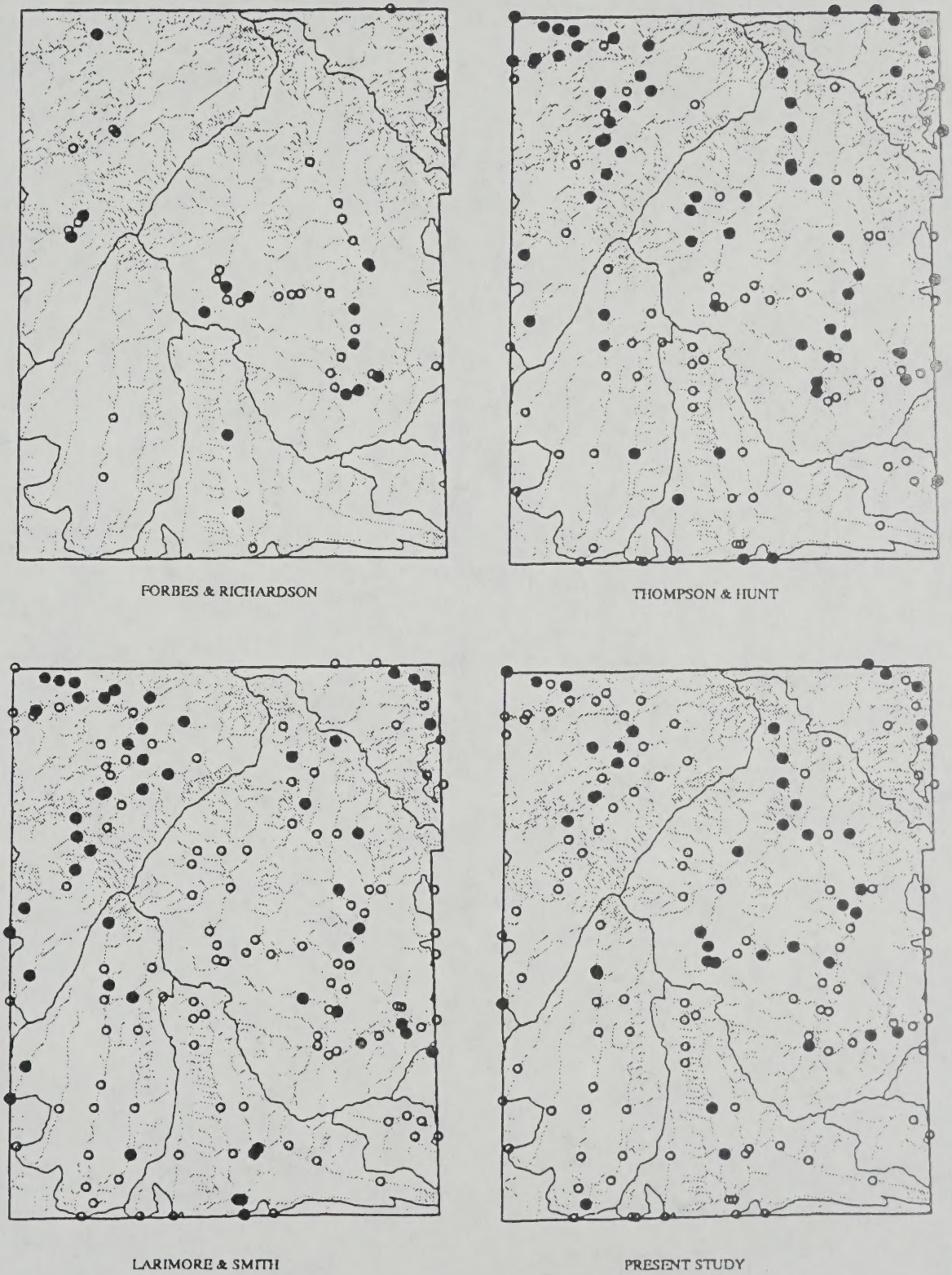


Fig A66. Closed circle -Presence, Open circle -absence of *Catostomus commersoni* White sucker (WHS) in Champaign County survey.

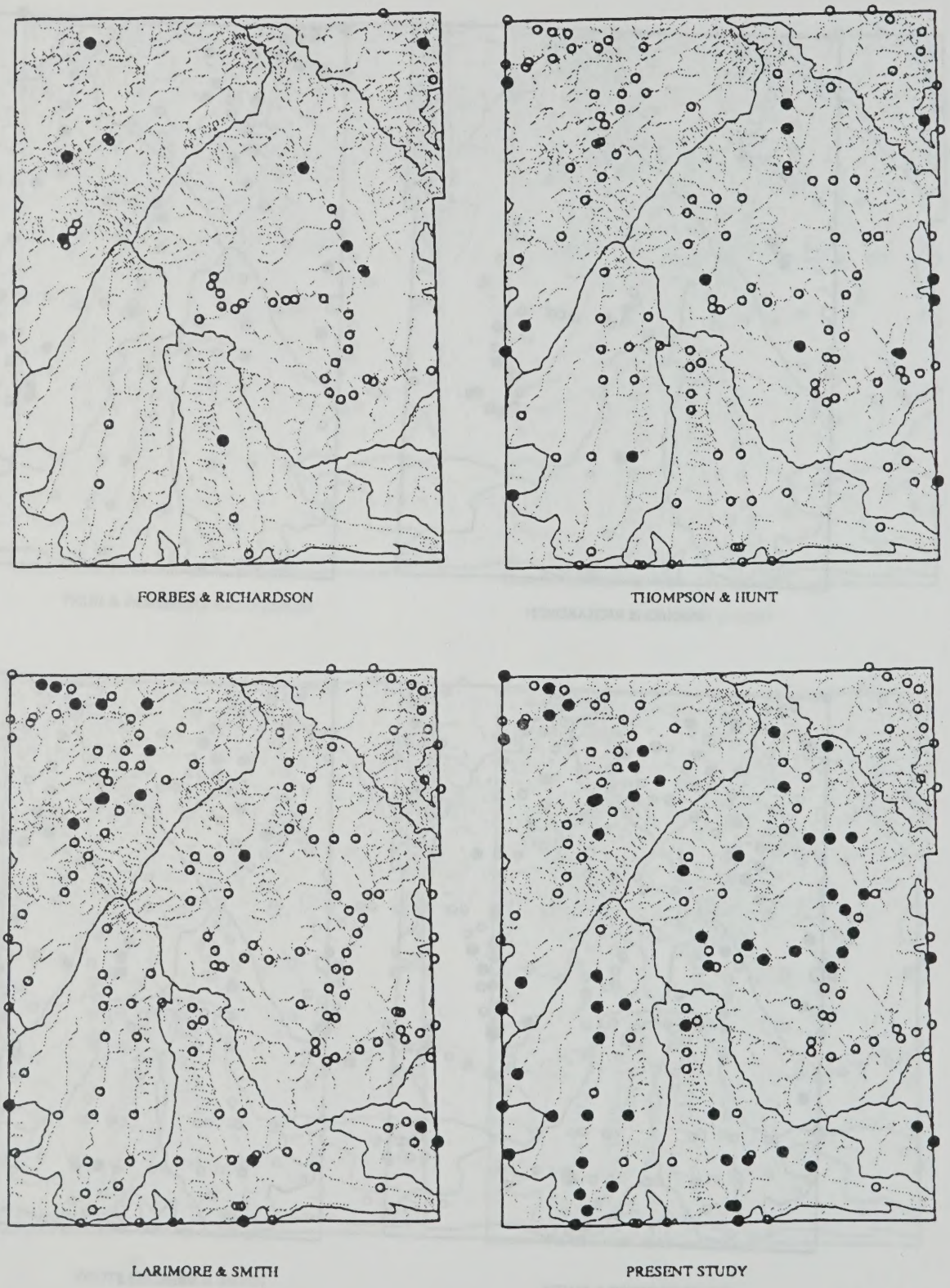


Fig A67. Closed circle -Presence, Open circle -absence of *Ameiurus natalis* Yellow bullhead (YEB) in Champaign County survey.

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